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# PAN AIR - A Computer Program for Predicting Subsonic or Supersonic Linear Potential Flows About Arbitrary Configurations Using A Higher Order Panel Method

## Volume II - User's Manual

(Version 1.0)

Kenneth W. Sidwell, Pranab K. Baruah, and
John E. Bussoletti

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## Volume II—User's Manual (Version 1.0)

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Naval Coastal Systems Center

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# 1.0 Introduction

PAN AIR is a system of computer programs for the detailed analysis and the non-iterative design of arbitrary configurations in steady, inviscid, subsonic and supersonic flows. PAN AIR uses a higher order panel method for the numerical solution of the appropriate linearized potential flow equations. The configuration surface is approximated by a set of panels on which unknown source and doublet singularity distributions are defined. By imposing boundary conditions at a discrete set of points, the integral equation solution to the partial differential equation is reduced to a system of linear algebraic equations relating the unknown singularity strengths. These equations are solved for the singularity strengths which in turn determine the properties of the flow field.

PAN AIR is called a higher order panel method because the singularity distributions are generally not constant on each panel. This property enables the doublet strength to be made continuous, a feature which is critically important for obtaining numerically stable solutions in supersonic flow. The method allows the analysis of flow about arbitrary configurations, reduces the sensitivity of the solution to the details of the panel layout, and also allows for higher efficiency in the analysis and solution procedures.

This document is the User's Manual for the PAN AIR software system. It contains detailed information on how to use the system. Other documents describe the technical aspects of the system. The PAN AIR Summary Document describes the scope and capabilities of the program system. The PAN AIR Theory Document contains a complete description of the theory and the solution procedures used in the program. The PAN AIR Maintenance Document describes the program structure and internal workings. The PAN AIR Case Manual contains a collection of flow problems solved by the program. The User's Manual and the Case Manual together will enable users to learn how to apply PAN AIR to commonly-encountered flow problems.

Section 2 of this document is a general description of the capabilities of PAN AIR, including both the engineering and software features. Section 3 is a beginner's guide which describes the application of PAN AIR to the most common aerodynamic analysis problem that users will encounter (flow past an impermeable "thick" object). This section serves as an introduction to the system, showing the user an application to an uncomplicated problem without concern for the generality of the system. Section 4 describes the PAN AIR system architecture and the individual technical modules. Section 5 describes the use of the program system (control cards, data bases, resource requirements, and modes of execution). Section 6 describes the use of the module execution control (MEC) "directives". Section 7 is a complete description of the engineering input data which specifies the aerodynamic problem to be solved. Section 8 describes the output data produced by PAN AIR.

Associated information is given in the appendices. Appendix A is a description of the boundary value problems that PAN AIR is designed to solve, including examples of well-posed and ill-posed problems. Appendix B is an extended description of configuration and flow-modeling in PAN AIR. Appendix C is a description of how to use the PAN AIR software in solving very large problems. Appendix D is a summary of the engineering input data formats.

## 1.1 Capabilities

PAN AIR includes the capabilities for both analysis and non-iterative design. The analysis capability has two parts. The first is an accurate calculation of the pressure coefficients and velocity components at any point on the configuration surface. The second part is the calculation of the force and moment coefficients acting on portions or on the entire configuration by integration of the surface pressure and mass flux contributions. The non-iterative design capability includes the analysis of the flow field resulting from a given configuration with a specified pressure coefficient or surface velocity distribution to obtain information for redesign of the surface to obtain the desired properties.

The capabilities of Version 1.0 PAN AIR can be applied to the solution of a variety of fluid flow problems. Specific capability features include the ability to:

1. analyze completely arbitrary configurations in subsonic flow and nearly arbitrary configurations in supersonic flow,

2. analyze either unsymmetric configurations or configurations with one or two planes of symmetry,

3. analyze configurations in either unsymmetric or symmetric flight conditions, including ground effect conditions,

4. analyze or design both geometrically thick configurations and thin configurations, such as, a camber surface representation of a thin wing,

5. analyze configurations either (in an exact sense) with boundary conditions applied on the configuration surface or (in a linearized sense) with appropriate boundary conditions applied to an approximation to the configuration surface,

6. analyze control surface deflections either (in an exact sense) by geometric deflection of the appropriate networks or (in a linearized sense) by imposing suitable boundary conditions on an approximation to the deflected control surface,

7. design the location of surfaces, including wakes, by the non-iterative design capability,

8. superimpose incremental velocity components onto the freestream either in a global sense, for example, additional velocity components to simulate a finite roll rate, or on a local basis, for example, to simulate different angles of attack for different networks or to simulate the effects of a slipstream or line vortex,

9. calculate pressure coefficients and force and moment coefficients by several pressure coefficient formulas (isentropic, linearized, second-order, reduced second-order and slender body),

10. calculate velocity components and pressure coefficients both at standard points and at user-designated arbitrary points on the configuration surface (flow quantities in the external flow field can be computed by using panels with zero singularity strength),

11. calculate the force and moment coefficients on individual panels, columns of panels, and networks, with the options of using user-specified reference dimensions and moment axes of either individual networks or the total configuration,

12. include or exclude the force and moment contributions of individual networks in the calculation of the force and moment coefficients of the total configuration,

13. calculate force and moment coefficients in the reference axis system (of the user-specified configuration), in the stability axis system, in the wind axis system, and in a user-specified body axis system, and

14. calculate leading and side edge forces, and moments due to singularity of the leading and side edge force distributions for thin configurations, and to include these calculations in the total configuration force and moment coefficients.

## 1.2 Summary

### 1.2.1 Functions Performed

The PAN AIR system is comprised of separate modules which were developed using an advanced software development approach called Systematic Software Development Methodology. This method emphasizes modular, structured software design. Thus the programs can be easily modified because changes in one module affect the other modules in a clearly identifiable manner. PAN AIR also includes features which improve the useability, maintainability and reliability of the program system relative to earlier versions of the panel technology, that is, the PAN AIR pilot code of references 1.1, 1.2 and 1.3.

Each PAN AIR module performs specific portions of the solution to a posed problem. A summary of their tasks is given as follows:

SDMS - Scientific Data Management System - allows definition of the various data bases used by the modules, and performs nearly all data transfers between core and disk.

MEC - Module Execution Control - generates the control card stream which will execute the required modules in the proper order based upon a set of user-supplied directives

DIP - Data Input Processor - processes the engineering input data required by all the modules except MEC

DQG - Defining Quantities Generator - transforms the input data of DIP into a useable form for the other modules

MAG - Matrix Generator - creates the aerodynamic influence coefficients in matrix form (that is, the coefficients of the linear system)

RMS - Real Matrix Solver - performs the triangular decomposition of the aerodynamic influence coefficient matrix so that forward-backward substitution may be used to solve the linear system of equations

RHS - Right Hand Side - generates the right hand side constraints (for example, multiple angles of attack) of the linear system and performs the forward-backward substitution to obtain the unknown singularities

MDG - Minimal Data Generator - constructs a data base containing a minimal set of geometry, influence coefficient and singularity data at control point and panel grid point locations for use by the downstream post-processing programs (PDP and CDP)

PDP - Point Data Processor - computes potential, velocity and pressure coefficient data at panel control and grid points and at user-specified arbitrary points on the configuration surface

CDP - Configuration Data Processor - computes force and moment coefficient data on the configuration and wake surfaces

PPP - Print Plot Processor - prepares a file of user requested data from DQG, PDP and CDP data bases in preparation for printing or for plotting by user supplied plotting routines

### 1.2.2 General Functional Flow

The PAN AIR software system determines the program modules execution sequence from the user defined input. The most common sequences for standard PAN AIR problems are depicted in figure 1.1. Other sequences are possible and can be easily constructed by the user with the MEC directives described in section 6. As the modules are executed, certain data bases are generated automatically but are later purged unless the user intervenes. It is the user's responsibility to save data bases needed for future runs.

### 1.2.3 Hardware Configuration

PAN AIR is designed to run on the Control Data Corporation 6600, 7600, and Cyber 175 computers under Scope 2.1, Scope 3.4, NOS 1.2 and NOS/BE operating systems. It requires under 130K octal words of central memory for standard runs and 75K octal words for non-standard runs using the post-processing modules. The system is designed to run in a batch environment because of a potentially large demand of computer resources such as CPU time and disk storage. Multiple disks (master and slaves) can be used for very large problems, see appendix C.

### 1.2.4 Program Configuration

PAN AIR consists of a total of ten program modules, a library of specialized and frequently used subroutines, and the Scientific Data Management System (SDMS).

PAN AIR was designed using SSDM (Systematic Software Development and Maintenance) techniques which are intended to insure maintainability and reliability of large software systems. It is written in FORTRAN IV language with imbedded design code comments following structured programming techniques. A few subroutines in the PAN AIR library and the SDMS are written in the COMPASS language.

Each of the PAN AIR modules generates a permanent SDMS data base for use by subsequent module(s). The execution control of the system is directed by the user through the PAN AIR MEC (Module Execution Control) module (see section 4.4). The problem definition of a PAN AIR run, the associated user directives and data are processed by the DIP (Data Input Processor) module and stored in the DIP data base for use by other, subsequent PAN AIR modules. The program limits (for example, the maximum number of networks) are listed in section 7.1.2.7.

The authors wish to acknowledge that portions of this report were prepared by Larry L. Erickson, NASA-Ames Research Center. The authors also wish to thank Paul E. Rubbert for his assistance in preparing the report and to thank Kathleen Crites for her efforts in typing this document and Gerard Bass and Sally Chapin for drawing the figures.

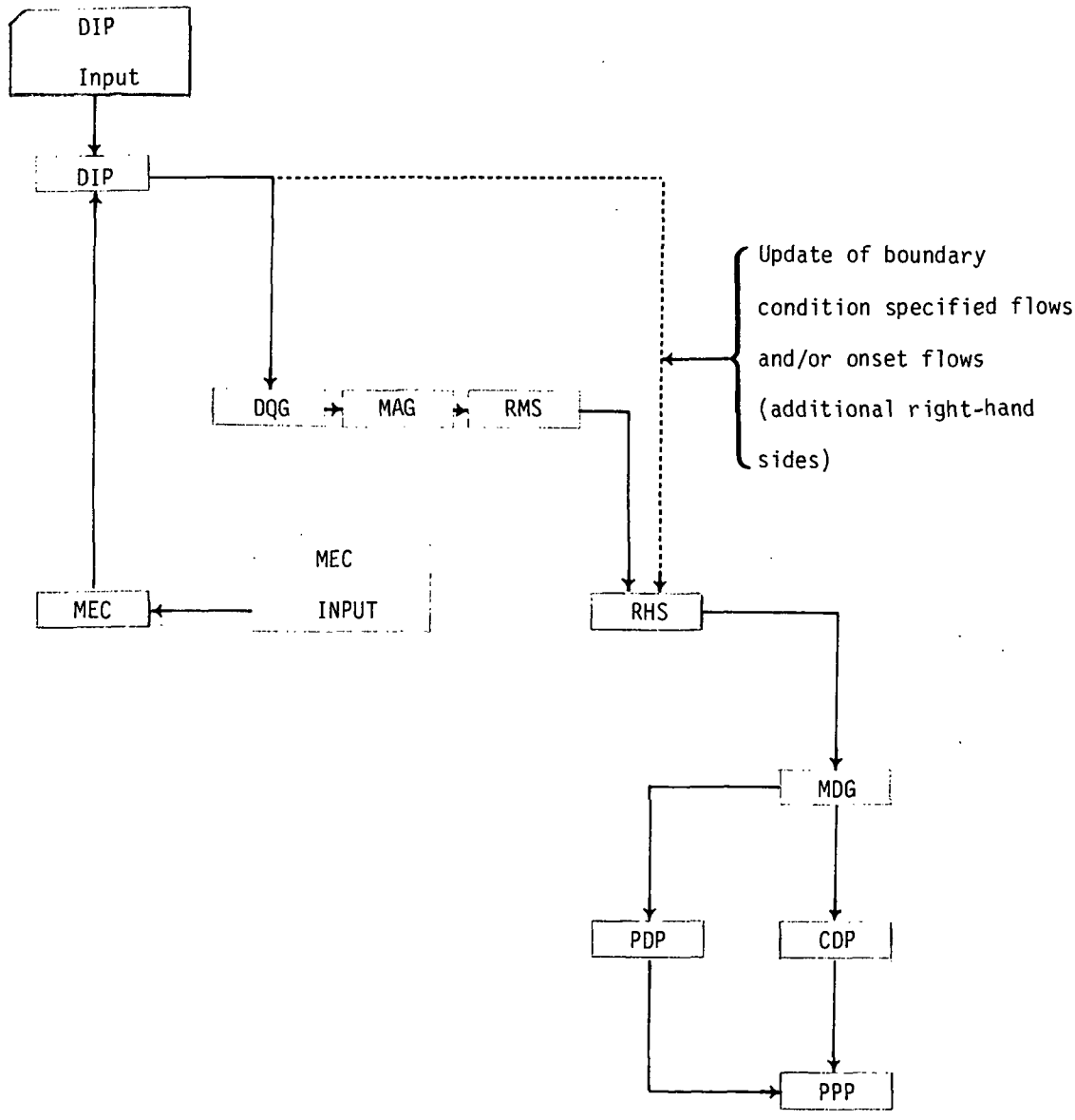



Figure 1.1 - Standard execution sequences of PAN AIR modules

## 2.0 PAN AIR Capabilities

PAN AIR offers a comprehensive aerodynamic analysis and design capability for nearly arbitrary configurations in subsonic and supersonic flows. The complexity of the problem formulation is determined by the user to suit his particular needs in terms of accuracy and resolution versus computing and manpower costs. The system can be applied to preliminary design problems, involving linearized modeling approximations for simple configurations. It can also be used in an "analytical wind tunnel" sense to determine detailed flow characteristics and the forces and moments about complex configurations.

PAN AIR is designed to permit efficient processing of configurations whose geometry differs locally from one already analyzed. Examples of this application are problems involving multiple control surface deflections and various store locations. Multiple flow cases involving, for example, several angles of attack or sideslip, or several inlet flow rates can be handled in one computer run.

PAN AIR is also designed to allow post-processing (data access, manipulation and display) to be performed independently of the initial data creation run: a minimal data set, generated as a result of the boundary value problem solution, is subsequently accessed and manipulated to produce output for multiple sets of user options. This process can be repeated several times. Data thus produced can be placed both on the PAN AIR data base and on a standard format plot file for subsequent plotting with user-supplied routines.

The PAN AIR system is capable of solving boundary value problems of the type governed by Laplace's equation:

$$\phi_{xx} + \phi_{yy} + \phi_{zz} = 0$$

or the wave equation:

$$\phi_{xx} - \phi_{yy} - \phi_{zz} = 0$$

or extensions characterized by the three-dimensional Prandtl-Glauert equation:

$$(1 - M_\infty^2)\,\phi_{xx} - \phi_{yy} - \phi_{zz} = 0$$

It is therefore suitable for the solution of problems involving nearly arbitrary configurations in subsonic or supersonic flows.

Limitations to the applicability of PAN AIR are governed by considerations as to whether the physics of the flow/configuration problem in question can be approximated to a reasonable extent by the inviscid, "potential flow" environment implicit in the use of the method. Applications of PAN AIR to transonic flow problems (in which subsonic and supersonic flows exist at the same time in different regions and which cannot be appproximated by either Laplace's equation or the wave equation) are clearly inadmissable. Similarly, application of the method to blunt configurations in either the high subsonic or low supersonic speed regimes should be limited to cases in which any local embedded supersonic or subsonic regions, respectively, are very small in

size. Use of the method for flows whose characteristics are appreciably affected by viscous phenomena (for example, thick boundary layers and separated regions) is of dubious value unless such layers and regions are simulated by the techniques of "displacement modeling" (see section 2.1.4). Application of PAN AIR in supersonic flow is limited to linear phenomena associated with weak shocks, for example, wave drag type pressures of thin airfoil theory; nonlinear phenomena such as those associated with strong shocks will not be predicted. Also, in supersonic flow solid boundary surfaces can not be modeled if the surface is at an angle to the undisturbed flow greater than the Mach cone angle.

PAN AIR can be applied in two general types of aerodynamic problems: analysis and design. Analysis boundary value problems (section 2.1) are of the following type: given the conditions in the undisturbed flow field and the flow conditions at the surface, find the resulting flow field. PAN AIR also has a non-iterative design capability (section 2.2) which solves problems of the following type: given the conditions in the undisturbed flow field and the desired pressure distribution at the surface, find the resulting flow field including data needed for linearized redesign to obtain the surface having the desired pressure distribution.

## 2.1 Aerodynamic Analysis Features

The PAN AIR aerodynamic analysis capability consists of the ability to:

(1) calculate pressures and velocity components at any point on the surface of a configuration, and

(2) calculate forces and moments both on the configuration as a whole and on specified portions of the configuration.

The detailed capabilities of the system are illustrated in the following descriptions of the analysis features.

### 2.1.1 Modeling Flexibility

From a geometric point of view, a configuration is amenable to processing by PAN AIR if the surfaces of the configuration can be approximated by "networks" of grid points which represent a mosaic of panels. The user specifies the geometry of the configuration by breaking it into a set of networks. Each network usually consists of a four-sided array of four-sided panels. The panels can be general quadrilaterals; their side edges need not be parallel to the flow. One side of a network can collapse to zero length so that the network becomes triangular.

The manner in which a configuration is constructed from a set of networks is illustrated in figure 2.1 for a transport type wing-body configuration. The networks are shown in a developed or "folded out" fashion. The number, sizes and arrangements of the networks are at the user's discretion within broad limits. (Restrictions on networks and panels are discussed in section B.1.3.) Usually networks will represent physically meaningful configuration components, such as major body components, fairings, and control surfaces.

PAN AIR uses higher-order panels which eliminate many of the modeling problems and restrictions that lower-order panels typically have. Two important aspects of the higher-order panels are that within a network (1) the doublet strength is continuous across all panel edges, and (2) all adjacent panels can have contiguous edges. This eliminates the generation of spurious line vortex behavior which can produce diasterous numerical effects in supersonic flow. Since the four corner points connected by a particular panel generally are non-planar, the continuous panel edge geometry is attained by folding the panel tips about lines connecting the panel midpoints. Thus each panel has a flat central portion and four flat, foldable triangular tips as shown in figure 2.2. The user inputs only the corner point coordinates from *which PAN AIR constructs the geometry of the folded panels.*

The user defines each network as a separate entity. This allows considerable freedom in modeling, but has the disadvantage that gaps (or overlaps) can be inadvertently created at network abutments. These gaps can cause spurious line vortex terms, which can produce serious numerical errors in supersonic flow. PAN AIR has the capability to detect such gaps and to create "gap-filling" panels that maintain continuous doublet strength across the network abutments (see section B.3.5). PAN AIR also allows the user to specify gaps in the configuration which are physically meaningful and thus to be retained in the analytical model.

Subsonically, the panels can be oriented arbitrarily in space. Supersonically, panels representing solid boundaries can still be inclined to the flow but they must be at angles less than the Mach angle. For nonsolid boundaries at angles greater than the Mach angle (for example, at an engine inlet or exhaust) a special "superinclined" panel can be used. Although the superinclined panels look like blunt surfaces, they do not influence the upstream flow. They are used to:

1. Seal off inlets to prevent the propagation of wave-like disturbances into the interior (which can degrade numerical accuracy).
2. Specify exhaust mass flows and capture oncoming inlet flows.
3. Close the interior volume so that velocity potential type boundary conditions can be specified on the interior surfaces of the panels.

Flows or mixtures of flows which exhibit "shear layers" and which can be rendered "simply connected" (see section A.3) by suitable paneling of such layers are frequently amenable to processing by PAN AIR. Such flows include wakes and free vortex sheets as shown in figure 2.3. Shear layers are modeled in PAN AIR by "wake networks." The most common application of wake networks is the simulation of wakes originating at the trailing edge of a lifting surface. PAN AIR does not calculate the shapes of wake networks unless indirectly as part of a design problem (see section 2.2); usually the user must provide approximate shapes for wake networks in the form of paneled surfaces, the quality of the solution being dependent on the quality of the approximation. Some examples of the modeling of shear layers are given in section B.3.6.

### 2.1.2 Configuration Symmetries (record G4)*

The PAN AIR user may take advantage of the geometric symmetry properties of the configuration to be processed. This reduces both the amount of data input and the cost of the solution. Even if configuration symmetry is involved, asymmetric flight conditions may still be processed, subject to the considerations described below in section 2.1.3. The symmetry option may be used not only for the obvious cases involving one or two planes of configuration symmetry but also for ground effect problems in which the "total" configuration consists of the vehicle itself and its reflected image.

The various classes of problems involving symmetry are discussed in the following.

#### 2.1.2.1 Asymmetric Configurations

PAN AIR is capable of handling completely asymmetric configurations. To accomplish this the user is required to provide panel arrangements for the complete configuration and any wakes or jets attached thereto. Examples of configurations which must be treated in this fashion are shown in figure 2.4 and include symmetric configurations with an asymmetric wake configuration, yawed wing configurations and aircraft with asymmetric stores arrangements. No configuration is completely symmetric of course, if only for the presence of small asymmetric elements. The choice of whether to consider the configuration as symmetric or asymmetric is the responsibility of the user and depends on the degree of detail desired in the analysis. Processing of asymmetric configurations is more expensive, in terms of both computer resources and input effort required, than processing of similar configurations with one or two planes of symmetry.

#### 2.1.2.2 One Plane of Symmetry

The one plane of configuration symmetry option can be used to handle efficiently two cases shown in figure 2.5:

(1) Configurations with one plane of symmetry. This case is typified by configuration symmetry about an arbitrary plane of symmetry, usually the plane $y_0 = 0$ (figure 2.5a). In this case the user must input either half of the configuration paneling, but forces and moments will be calculated as if the whole configuration were present.

(2) Asymmetric configurations in ground effect. In this case the single plane of configuration symmetry may be used to represent a ground plane. This capability may be used not only for truly asymmetric configurations in ground effect but also for configurations at some angle of bank

---

* Configuration symmetries are specified by record G4 of the DIP module input data. Record identifiers and names are listed in section 7.2.2; records are described in sections 7.3 to 7.7.

relative to the ground (figure 2.5b). (Configurations with one plane of symmetry at zero angle of bank in ground effect may be dealt with by using the two planes of symmetry capability described below.) When a ground plane is specified, forces and moments are not calculated for the "image half" of the "total" configuration.

### 2.1.2.3 Two Planes of Symmetry

In the two planes of symmetry option the two planes must be orthogonal, that is, at right angles to each other, but otherwise may be selected arbitrarily. One or both planes may be used as a ground plane on instruction from the user. Again, a ground plane is differentiated from an "ordinary" plane of symmetry in that forces and moments are not computed for the associated "images" in the case of the ground plane. The two planes of configuration symmetry option can be used to handle efficiently three cases shown in figure 2.6:

(1) Configurations with two planes of symmetry such as the "cruciform" configuration shown in figure 2.6a. In this case only one quarter of the vehicle and wake paneling need be input.

(2) Configurations with one plane of symmetry in ground effect, in which case one half of the vehicle, that is, one quarter of the "total" configuration, is input (figure 2.6b).

(3) Flow about an arbitrary object positioned in the "corner" between two perpendicular walls (figure 2.6c), the flow being along the walls. The complete object, which is one quarter of the "total" configuration, is input in this case.

Special treatment is required for networks which lie in a plane of symmetry, for example, a planar, thin surface representation of a vertical fin lying in the plane $y_0 = 0$. Such networks are identified by a "reflection in plane of symmetry tag" (record N5), which instructs the program to specially treat the "images" of the network in question. Alternately, a network is determined by the program to lie in a plane of symmetry if its panel center points lie in the plane of symmetry.

### 2.1.2.4 Asymmetric Flow Cases for Symmetric Configurations

Problems whose panel geometry contains a plane of symmetry can take advantage of symmetry economies even though the boundary conditions and/or the onset flow are not symmetric. For example, a configuration with one plane of $x_0$-$z_0$ symmetry at an angle of sideslip falls into this category. Program economies are achieved by decomposing the effective incident flow into symmetric and antisymmetric components, solving these two separate boundary value problems, and then summing the solutions to obtain the final, asymmetric results. With one plane of symmetry two sets of N equations are solved, rather than a single set of 2N equations. Certain restrictions are implicit in this capability when compressible flow cases are considered as shown in figure 2.7:

(1) For one plane of configuration symmetry, the compressibility direction (which is the x direction in the Prandtl-Glauert equation) must lie in the plane of configuration symmetry (figure 2.7a).

(2) For two planes of configuration symmetry, the compressibility direction must lie in both planes of symmetry and hence must be in the direction of the intersection of the two planes (figure 2.7b).

These conditions restrict the use of the configuration symmetry options. If the restrictions on the compressibility direction are not met, the user either must forgo use of the configuration symmetry option(s) or must use approximations in modeling the onset flow field.

The direction of the "uniform onset" flow velocity $\vec{U}_\infty$ may deviate from the compressibility direction, but such deviations should be limited to small angles to maintain the validity of the linearized compressible formulation. For example, for the singly symmetric configuration at an angle of sideslip $\beta$ in figure 2.7a, that angle should be small, while for the cruciform configuration in figure 2.7b both angles of attack $\alpha$ and sideslip $\beta$ should be small. (The distinction between the compressibility direction and the direction of the uniform onset flow is discussed further in section B.2.2.) The allowable range of the angles of attack and sideslip should be reduced as the Mach number is increased. Typical ranges are $\pm 10^\circ$ at Mach = 0.5, $\pm 5^\circ$ at Mach 1.3 and $\pm 1^\circ$ at Mach = 3.0. For asymmetric flight conditions in compressible flow in which these angles are not small, the configuration must be treated as asymmetric. However, these restrictions do not apply in incompressible flow, where any configuration with geometrical symmetry can be treated in this fashion regardless of the magnitudes of the angles of attack and sideslip. The symmetry option can also be used for configurations whose panel geometry is symmetric but whose boundary conditions are not. Examples of this are asymmetric flow due to linearized control surface deflections modeled through the boundary conditions (see sections 2.1.4 and B.3.2) rather than by deflecting the actual control surface networks (figure 2.8a), and due to propeller discs with differing influxes (figure 2.8b).

### 2.1.3 "Thick" and "Thin" Configurations

The fundamental "composite panel", with two boundary conditions per control point, provides the PAN AIR user with a great deal of flexibility in dealing with various types of configurations.

In the most frequent type of usage, panels are distributed over the surface of a "thick" configuration (that is, one in which the surface encloses a finite volume, for example the "thick" wing section shown in figure 2.9a) to provide a detailed simulation of the surface shape. The two boundary conditions on each panel control not only the flow around the outside of the vehicle, but also the flow in the interior of the configuration which, although of no physical significance, is required to render the solution unique (see section A.3). (In most thick configuration cases the interior flow will be set equal to the freestream velocity by the selection of standard boundary conditions and need not be of concern to a majority of users.)

Some types of problems however may warrant a "thin" surface treatment in which the panels are used to simulate both the upper and lower surfaces of an infinitely thin wing, for example. In this case, the interior volume is non-existent and the two boundary conditions control the outer flow over both upper and lower surfaces of the wing (figure 2.9b). Presumably, in this type of usage the configuration will be sufficiently thin to warrant thin surface treatment and, furthermore, the user will be aware of the accuracy limitations imposed by the approximate nature of the configuration simulation. Thin surface simulation will usually be substantially cheaper in terms of computer time and cost, and input effort required, than corresponding "thick" configuration cases. This provides the user with an important flexibility in weighing his requirements in terms of accuracy versus incurred cost.

Techniques are available which will increase the configuration fidelity of thin surface representation. For instance, finite wing thickness may be simulated with a thin surface network representation by specifying a source singularity distribution (in addition to the doublet distribution) whose strength is equal to the rate of change of thickness. Such "linearized" modeling techniques are described below in section 2.1.4. Both "thick" and "thin" surface representations may be used in the same analysis as shown in figure 2.9c.

### 2.1.4 "Exact" and "Linearized" Modeling

The terms "exact" and "linearized" pertain to whether the boundary conditions applied on the network surface representation are used to represent the flow conditions at the network surface itself (exact), or at some small, non-zero distance away from the network surface (linearized).

Consider the example of a paneled surface representation of a thick wing. If the user were interested only in the characteristics of the wing in potential flow, he would specify appropriate "exact" boundary conditions at the surface of the paneling scheme which would enforce the condition of zero flow normal to the exterior of the wing (plus a suitable representation of the interior flow). If on the other hand, he were interested in simulating the boundary layer thickness on the surface of the wing, he could do this by using either exact modeling or linearized modeling.

In exact modeling, he would estimate the diplacement thickness of the boundary layer at all points on the wing surface, add this thickness to the wing profile, panel the shape of the wing plus boundary layer and apply exact boundary conditions at the displacement surface of the boundary layer (figure 2.10a). This is an example of "exact displacement modeling." Modeling of the displacement surfaces in figure 2.10a would require two wake networks, one for upper and one for the lower shear layer.

Using linearized modeling on the other hand, he would simulate the effects of the boundary layer without repaneling the shape of the wing plus boundary layer by imposing suitable "linearized" boundary conditions (or by imposing local onset flows discussed in section 2.1.5), which would be applied on the surface of the wing, but would simulate conditions at the displacement surface of the boundary layer. In practice he would do this by specifying a source strength distribution which would produce a flow out of the paneled surface equal to the rate of change of boundary layer thickness (figure 2.10b). This is an example of "linearized displacement modeling".

Note that the terms "exact" and "linearized" in this context do not imply any assumptions as to whether the paneling scheme used is "thick" or "thin." Both exact and linearized modeling techniques can be used on either thick or thin surface representations. Use of exact modeling is fairly self-explanatory. Use of linearized modeling is explained by the applications described below. (The associated boundary condition equations and their implementation in PAN AIR are discussed in section B.3.2.)

#### 2.1.4.1 Boundary Layers

The linearized representation of boundary layers was illustrated in the example discussed above.

#### 2.1.4.2 Thickness Distributions

The simulation of thickness for a thin wing surface representation, or increments in thickness on a thick configuration, is a problem very similar to that of boundary layer simulation. In both cases, additional source strength is specified on the surface equal to the rate of change of thickness, incremental thickness or boundary layer displacement thickness (figure 2.11a).

#### 2.1.4.3 Camber Distributions

The effects of camber or incremental camber can be simulated for both thick and thin surface representations by specifying an incremental flow through the paneled surfaces equal in magnitude to the difference in camber slopes between the paneled configuration and the simulated configuration. The direction of the incremental flow is from the paneled surface to the simulated surface (figure 2.11b).

#### 2.1.4.4 Linearized Control Surface Deflections

The simulation of control surface deflections is essentially the same problem as simulation of incremental camber distribution described above. For example, in simulating a flap deflection, an incremental flow equal to the tangent of the flap deflection angle and flowing from the paneled surface to the simulated surface would be specified (figure 2.11c).

#### 2.1.4.5 Linearized Asymmetric Effects

Asymmetric control surface deflections, for example, aileron deflections, or asymmetric distributions of camber or thickness can be simulated even if only one half of a configuration with one plane of symmetry is used as the paneling scheme (figure 2.8a). This is possible because no actual change in network geometry between "real" and "image" halves of the configuration is

involved. The user exercises this capability by specifying an additional set of boundary condition data on the appropriate "image" network(s). These inputs are of course different from those for the corresponding "real" network(s). This option is not available if the plane of symmetry is designated as a ground plane. Also, asymmetric power effects may be simulated using only one side of a symmetric configuration as a paneling scheme. This could be performed by specifying, for example, a flow through an "image" actuator disc (propeller disc) which is different from that on the "real" paneled disc, again assuming that the slipstream shape is the same for both "image" and "real" halves of the configuration (figure 2.8b).

#### 2.1.4.6 Flow Entrainment by Jet Effluxes

In analyses involving V/STOL aircraft in hovering flight or at low forward speeds, the flow entrained by lifting jets or slipstreams exerts an appreciable influence on the forces and moments experienced by the vehicle. These effects can be modeled using linearized techniques in a manner similar to that used in modeling linearized boundary layer effects. The efflux would be treated as an extension of the configuration and modeled with composite panels. (The user must assume the location of the "efflux tube" extension.) Boundary conditions would be imposed such that the source singularities are used to simulate specified inflow (entrainment) rates at each control point (figure 2.11d), see section B.3.6. These inflow rates could be obtained from appropriate test data or analysis involving mixing jets.

### 2.1.5 Onset Flows

In PAN AIR the configuration being analyzed is assumed to be at rest with respect to an inertial frame of reference, which is defined by the "reference coordinate system" $(x_0, y_0, z_0)$ used to input the configuration geometry. In the most frequent type of usage, the configuration is exposed to a uniform onset or freestream flow velocity $\vec{U}_\infty$ whose direction relative to the reference coordinate system is determined by the angles of attack and sideslip specified by the user. In addition to the freestream, the user may specify incremental flows of two basic types (figure 2.12).

#### 2.1.5.1 Rotational Flows (record set G6)

These are used for simulation of steady rotational motions, for example, rates of roll, pitch and yaw or rates of rotation about arbitrary axes, which must be regarded as "quasi-steady" states because the configuration is fixed in inertial space (figure 2.12a). In PAN AIR the flow is rotating with respect to the fixed vehicle; for a rotating vehicle simulation the user must specify the negative of the vehicle rotation rates.

#### 2.1.5.2 Local Onset Flows (record set N18)

The user may impose additional velocity components by specifying the components of a local onset flow on the configuration. This option may be

used on a per-network basis to simulate in a linearized fashion such effects as a change in wing incidence relative to the remainder of a configuration, or a change in attitude of a model relative to a wind tunnel, without changing the geometry of the panel arrangement (figure 2.12b). In addition, the local onset flow may be varied from panel to panel within a network or group of networks (figure 2.12c). This is useful, for instance, in simulating the flow of a swirling, non-uniform slipstream over the surfaces of a wing or nacelle. In using this option, the user would specify the local onset flow at each control point in the network. The user has the additional option of specifying the local onset flow either as three velocity components or as a velocity magnitude and angles of attack and sideslip. In addition to entering into the boundary value problem solution, the incremental flows can be included in subsequent pressure coefficient calculations. This permits the calculation of more realistic pressure coefficients in situations which simulate locally higher energy flows such as slipstreams.

### 2.1.6 Surface Flow Property Options

Surface flow properties, that is, the velocities and pressures, can be calculated in various ways and in varying detail at the discretion of the user. The program will follow one or more paths in calculating these quantities, depending on the user's choice from the options listed below.

All options have system defaults; if the user does not specify a particular choice, the system chooses the default. The options and system defaults are summarized in figure 2.13. The user can change the system defaults by using the Global Data Group records (section 7.3) to specify a new set of system defaults, including multiple selections of most options. In addition the user can select an alternate set of options for each "case" of post-solution computations by using appropriate records in the Surface Flow Properties Data Subgroup (section 7.6.1).

#### 2.1.6.1 Surface Selection Options (records G8 and SF5)

PAN AIR solves for both "exterior" and "interior" flows. Data can be calculated and printed for both "upper" and "lower" surfaces of each singularity sheet (see section B.1.1). Data can also be calculated and printed for the difference and average of the upper and lower surface data.

#### 2.1.6.2 Point Location Options (record set SF4)

Several choices of point locations at which surface flow properties are calculated are available. These options are

(1) panel center control points,

(2) network edge control points,

(3) an "enriched grid" of points consisting of points on each panel: the center point, the four corner points and the four edge midpoints, and

(4) user-specified points on the surface.

The choice of these options can be varied from network to network. Required computing resources will of course increase as the number of calculation points increases.

2.1.6.3 Velocity Computation Methods (records G9 and SF6)

Two options are available for the method of computing velocities on the network surfaces:

(1) by using the analytically differentiated surface potential distribution, together with the appropriate flow normal to the surface as defined by the boundary conditions and the known jump conditions across each panel (BOUNDARY-CONDITION method), and

(2) by using the "velocity influence coefficients" used to construct the aerodynamic influence coefficients (VIC-LAMBDA method).

Because of its efficiency, method (1) would be used in the majority of cases involving conventional modeling techniques and boundary conditions. Method (2) is intended for use in cases involving unusual boundary conditions or modeling techniques. If both methods are specified, two independently computed sets of results will be produced.

2.1.6.4 Velocity Correction Options (records G11, SF10b and SF11b)

Because of the small perturbation assumptions implicit in the Prandtl-Glauert equation, errors are introduced into the compressible velocity computations when the local velocity deviates substantially from the freestream. The largest such deviations occur in and around stagnation regions such as at wing leading edges and inside inlets. To produce realistic velocity and pressure results in these regions, two independent velocity correction techniques are available which may be applied whenever the panel method predicts large, negative perturbation velocities. The first correction is used to correct the velocity at a blunt leading edge. It is useful for thick unswept wings or flow-through nacelles. The second correction is used to correct the velocity for predicting the outer flow in a boundary layer analysis. It is useful for thick wings or wing-like configurations. The velocity corrections are discussed in section B.4.1.

2.1.6.5 Pressure Coefficient Rules Options (records G12, SF10c and SF11c)

Once the user has decided on the method(s) of computing velocities, he may similarly exercise several options for computing the pressure coefficients from the velocities. The pressure coefficient rules available are: isentropic, linear, second-order, reduced second-order, and slender body. These formulas are discussed in section B.4.2. The isentropic pressure formula usually gives the best results with exact surface paneling. The

others represent varying degrees of approximation to the isentropic formula and are often used in conjunction with linearized modeling techniques. Another option is available in the form of a user-specified pressure reference velocity (records G14 and SF9). This is used in calculating pressure coefficients for stationary configurations, for example, an engine operating under static conditions.

#### 2.1.6.6 Wake Flow Properties

The flow properties on the surfaces of wake networks can be calculated if desired. This option is useful in determining whether the wake location specified by the user is a reasonable representation of that which would occur in practice: large flow velocities normal to the wake imply an inaccurate estimation of the wake location. In many instances (for example, simple wing-body configurations) this is not of serious consequence. However, in some instances the wake location is crucial to the flow characteristics, for example, a closely coupled tail or canard in which the wake from the forward surface passes close to the aft surface. In such cases it may be necessary to perform an iterative cycle of calculations to determine the correct wake location. The wake flow properties will yield information from which a second iteration of the wake location can be estimated.

### 2.1.7 Force and Moment Calculation Options

Force and moment coefficients can also be calculated in various ways and in varying detail at the discretion of the user. These calculations are carried out independently of the options selected for surface flow properties calculations described above. The options and system defaults are summarized in figure 2.14. The defaults, either program defaults or user-specified defaults, are the same as for the surface flow property computations. The user can select alternate options for each "case" of computations by using appropriate records in the Forces and Moments Data Subgroup (section 7.6.3).

#### 2.1.7.1 Surface Selection Option (records G8 and FM12)

Force and moment coefficents can be calculated for the upper and lower surfaces of each singularity sheet and for the sum of the upper and lower surface values.

#### 2.1.7.2 Force and Moment Computation and Summation Options (records FM5 and FM19)

The force and moment coefficents can be computed, printed and summed in varying degrees of detail:

(1) for each panel,
(2) for each column of panels in a network,
(3) for each network, and
(4) for the user-specified configuration for each case.

The choice of options (1) to (3) can be varied from case to case as specified by the user. These options permit, for example, the evaluation of wing loading and bending moment distributions. An additional option enables individual networks to be eliminated from the force and moment summation for the total configuration. For example, a wind tunnel mounting system can be modeled, but the networks simulating the mounting system eliminated from the force and moment calculations.

2.1.7.3 Velocity Computation Methods (records G9 and FM13)

The options available are identical with those available for surface flow properties (see section 2.1.6).

2.1.7.4 Velocity Correction Option (records G11 and FM15)

The options available are identical with those available for surface flow properties (see section 2.1.6).

2.1.7.5 Pressure Coefficient Rules Options (records G12 and FM16)

The options available are identical with those available for surface flow properties (see section 2.1.6).

2.1.7.6 Edge Force Option (record FM9)

The velocities and pressures near subsonic leading and side edges of lifting surfaces exhibit very high local velocities. Reasonably accurate integrations of the "leading edge thrust" force produced by this behavior can be obtained for thick wings with dense leading edge paneling. However, for thin wings (in which case the velocities become infinite), integration of surface pressures omits the edge force effect, thereby yielding unrealistic drag forces. In PAN AIR an option is available by which the edge force can be calculated by extrapolating the component of velocity normal to the edge (and in the plane of the panel) towards the edge in an inverse square root fashion (see section 0.3 of the Theory Document). The force thus calculated is added to the forces obtained by integration of the surface pressures.

2.1.7.8 Axis Systems Options (record FM3)

Force and moment coefficients can be calculated and printed in several axis systems, each with a user-selected moment reference point. The options available and the defaults for the coordinate systems are:

(1) Reference Coordinate System
In this system the $x_0$, $y_0$, and $z_0$ directions are those used to define the configuration geometry. In the default system the $x_0$-axis points

toward the tail of the configuration; the $y_0$-axis points toward the starboard wing; the $z_0$-axis, forming a right-hand set, points vertically upward.

(2) Stability Axis System
The (wind tunnel) stability axis system is obtained from the reference coordinate system by a rotation of (minus one times) the angle of attack about the $y_0$-axis.

(3) Wind Axis System
This system is defined from the reference coordinate system by rotations given by (minus one times) the angles of attack and sideslip such that the x-axis points downstream in the relative wind direction, the y-axis toward starboard and the z-axis upward. This system produces forces consistent with commonly-accepted lift and drag definitions (for example, reference 2.1, also see section B.4.3).

(4) Body Axis System
An arbitrary body axis system can be specified by supplying an origin and Euler angle rotations away from the reference coordinate system. The default body axis system is constructed such that the x-axis points forward and the z-axis downward. This system produces forces and moments consistent with commonly-accepted stability and control practice, for example, starboard wing down produces positive roll angle and starboard wing aft produces positive yaw angle.

#### 2.1.7.9 Reference Dimensions Option (record FM2 and FM11)

The user can specify reference values for chord and span lengths and for surface area, which are used in computing the force and moment coefficients.

## 2.2 Aerodynamic Design Capabilities

The PAN AIR design capability, termed "non-iterative" design, consists of the ability of taking a first approximation to the shape of a portion of a configuration, together with a specification of the desired pressure or velocity distributions on that portion and transforming these data into relofting information, from which a second estimate of the desired shape can be calculated. Application of this technique to thick and thin configurations is illustrated in the following paragraphs.

### 2.2.1 Thick Configuration Design

Application of non-iterative design to a portion of a thick wing is illustrated in figure 2.15. The user starts with a paneled approximation to the surface to be designed and a desired pressure or velocity distribution over that surface (figure 2.15a). The pressure or velocity distribution is then converted by the user into tangential velocity boundary conditions applied at the panel center control points of the network in question (figure 2.15b), see

section B.3.3. The tangential velocity boundary conditions apply only to one surface of the network under consideration, in this case the "upper" surface; another set of conditions, in this case zero perturbation velocity potential, insures uniqueness of the internal flow.

The doublet singularities in the design application are represented by a different type of network to that used in analysis problems: an extra degree of freedom is required in both row-wise and column-wise directions. Special edge conditions are used to control these degrees of freedom. A "closure" integral condition is imposed at one "free" edge. In this instance, setting the integral to zero insures that both leading and trailing edges of the network remain in their original locations when the surface is redesigned. The "matching" condition applied at the other "free" edge imposes an appropriate doublet strength (figure 2.15b).

The end result of the process is shown in figure 2.15c. The tangential flow conditions are satisfied in the solution but conditions normal to the panel are left free, except that the closure condition controls the integral of the normal flow along a particular column. The residual normal flows at each control point can be shown, using linearized assumptions, to be equal to the difference in slope between the approximated surface and the desired surface. This information is used (external to PAN AIR) to reloft a second iteration of the desired shape.

### 2.2.2 Thin Configuration Design

The design process can be applied to "thin" configurations as illustrated in figure 2.16. Figure 2.16a shows a situation in which the camber surface of a thin wing is to be designed to produce a given loading. Boundary conditions in this case would consist of "difference" tangential velocities, which prescribe the load distribution, and "average" tangential velocities of value equal to the freestream, which set the source strength on the composite panels everywhere equal to zero. A matching edge condition must be applied to the leading edge to set the doublet strength equal to zero. This uses up the degree of freedom available in the streamwise direction so that no control over the relative locations of leading and trailing edges can be exercised.

Figure 2.16b shows the design of a "thick" wing using a "thin" surface representation. Tangential velocity boundary conditions are used to specify the pressure distributions on both "upper" and "lower" surfaces individually. The program decomposes these into "difference" tangential velocities which prescribe the loading and "average" tangential velocities which indirectly determine source strength distributions, thus describing the thickness slopes. Both closure and matching conditions are applied to insure zero leading edge doublet strength and a "closed" thickness form, respectively.

## 2.3 System Usage Capabilities

PAN AIR offers several modes of operation other than the "normal" one-pass, input-solution-output mode. These modes are designed to facilitate use of the system with regard to data checking and resource estimating,

processing of additional flow cases, processing of configurations which differ in a limited way from a previously-analyzed problem, and extraction of data after the initial data-creation run.

### 2.3.1 Data Checking and Resource Estimation

The problems submitted to PAN AIR may involve large amounts of input data. Rather than risk wasting computing resources on an incorrectly formulated or erroneous submission, the user is able to take advantage of the data checking, diagnostic and resource estimating capabilities of the system.

To use this capability the user submits a complete input deck along with a "CHECK DATA RUN" as a MEC data command. The latter instructs the system to execute the first two programs, the DIP (Data Input Processor) and DQG (Defining Quantities Generator) modules, read and echo the user-supplied input information, check for syntactical errors, problem formulation errors and logic errors, and print diagnostic messages describing each error in easy-to-understand terms. The DQG module sets up the boundary value problem as though a full system execution were requested, including the indexing of all networks and panels, the construction of network abutments and the assignment of boundary conditions. DQG prints all pertinent geometric data, sets up a file for configuration panel display and estimates the computing resources (core size, disk storage size and central processor time) required for full problem execution. Execution of the data check process is terminated only in the case of major input errors which cannot be resolved without user intervention. This permits the detection of multiple errors in one submission. Further details on the data check capability are in section 6.

### 2.3.2 Additional Flow Cases ("Solution Update")

The boundary value problem formulation and solution ultimately involve the construction and solution of a system of linear algebraic equations, which can be expressed in matrix form as:

$$[AIC] \quad \{\lambda\} \quad = \quad \{b\}$$

In this equation $\{\lambda\}$ is the set of unknown source and doublet singularity parameters to be solved for. The matrix [AIC] is composed of "aerodynamic influence coefficients" which describe the influence of a particular singularity parameter on a particular boundary condition. These influence coefficients are purely geometric in nature and involve terms which describe the relative locations of panels and control points, describe the "type" of boundary conditions at these particular control points (for example, normal vectors for analysis conditions, tangent vectors for design conditions) and involve Mach number dependent geometry scaling vectors. These terms are collectively referred to as "left-hand side" quantities.

The vector $\{b\}$ consists of scalar boundary condition terms which are primarily flow condition related. Such quantities as the magnitude and direction of the freestream or "onset flow" and the magnitudes of imposed velocities at control points are represented in this vector. These terms are

referred to as "right-hand side" quantities.

The construction and triangular decomposition of the AIC matrix is the most costly and time consuming operation in PAN AIR. Once this is performed, multiple solutions involving different "right-hand sides" can be executed economically.

In PAN AIR, multiple flow cases can be processed in the initial submission. In addition, the decomposed AIC matrix can be saved and new "right-hand sides" processed after the initial submission. In using this capability, a single "STORE AIC" MEC data command accompanies the original run. Subsequent submissions contain the MEC data command "SOLUTION UPDATE" and the data needed to specify the new solutions. Use of this capability enables the user to cover a range of flow parameters in a coarse fashion on the first submission, determine a range of interest from this initial scan, and then selectively process additional flow cases in the range of interest.

### 2.3.3 Limited Configuration Changes ("IC Update")

Situations arise in which it is desired to process configurations which differ from one already processed in a limited fashion with respect to geometry and/or boundary condition type. This type of change, as opposed to a "SOLUTION UPDATE," involves changes in the "left-hand side" information which appears in the AIC matrix, and can be handled efficiently by an "IC UPDATE" (IC, influence coefficient) capability.

In the original submission the user appends an "updateable" label to selected networks or network edges (record N8). This tells the program that the influence coefficients and equations involving these networks or edges might be recalculated in subsequent cases. The program then blocks the solution matrices so that the coefficients not involved in the change are calculated once and saved, while those which are involved are placed at the end of the set of equations so they can be recalculated as part of the processing of subsequent run(s).

The input listing for the subsequent submission involving the change contains a label which identifies it as an "IC UPDATE" run, plus a redefinition of only those networks which were labeled as "updateable" in the original submission. This redefinition can involve changes in the geometry of the network, the "type" of boundary condition or a combination of the two. The equation solver then takes advantage of the fact that the matrix contains a block of terms which remains constant for each subsequent case.

This feature is designed to enable the user to execute efficiently the following types of cases.

#### 2.3.3.1 Design

When more than one iteration is desired in the design process, the IC update capability should be used. The process is illustrated in figure 2.17. In this thick wing design problem, the network representing the wing is

subject to changes in shape from iteration to iteration. It is thus labeled "updateable." The shape of the trailing edge will also presumably be changed and so the wake network which abuts the trailing edge must also be labeled updateable. The shape of the wing-body intersection curve and the intersection curve of the wake with the body to some distance aft of the trailing edge will also change, and so portions of the body immediately above and below the wing and wake (referred to in the drawing as upper and lower wing-body fairings) must be labeled updateable. Note that the extent of the updateable regions of the configurations can be limited by judiciously splitting up major components into small networks. In the subsequent update run, the user may wish to analyze the resulting modified shape, rather than perform a second design iteration. In this type of application, in addition to perturbing the geometry, he would also change the type of boundary condition from design to analysis in his second submission.

#### 2.3.3.2 Addition or Deletion of Configuration Components

Addition or deletion of a horizontal tail, for example, can be accomplished using the IC update capability. Figure 2.18 illustrates two slightly different situations. In figure 2.18a, networks representing a thick horizontal tail and the tail wake are to be added or deleted from the configuration. If the tail is to be added, it will be absent in the original run and the body networks immediately above and below the tail location will meet at a common boundary. In the subsequent update run, the networks representing the tail and wake will be added and the edges of the body networks shifted to form the shape of the body-tail intersection contour. In the original run, those upper and lower body networks will therefore be labeled updateable. If the tail is to be deleted, the reverse process occurs. However, since the tail and wake networks are present in the original run, they, in addition to the body networks, must be labeled updateable. In the subsequent update run, the tail and wake networks will not be present and the body networks will be modified to "fill the gap" in the body side. A slightly different situation is shown in figure 2.18b. Here, the tail is represented by a "thin" surface and the body networks meet at the line representing the body-tail intersection. Since addition or deletion of the tail does not require a change in this intersection line, the body networks need not be labeled updateable. However, the edge boundary conditions along the abutment of these networks will change upon addition or deletion of the tail. These edges must therefore be labeled updateable. If the tail and wake networks were present in the original run, these networks would be labeled updateable.

#### 2.3.3.3 Successive Control Surface Deflections

Use of the IC update capability in analyses involving successive control surface deflections is illustrated by figure 2.19. It is assumed that in the original run the surface is in the undeflected position as shown in figure 2.19a. Both the control surface and its trailing wake will be moved in the following runs, so they must be labeled updateable. Although the aft, outer wing surfaces remain fixed, conditions at their inboard edges will change, and so these edges must be labeled updateable edges. Additional wake networks will be added in the subsequent deflected cases as shown in figure 2.19b.

#### 2.3.3.4 *Stores Separation*

Successive locations of a jettisoned external store may be modeled efficiently by the updateable feature. The group of networks representing the store itself and the wake emanating from the store would be designated as updateable in this case.

### 2.3.4 Separate Post-Processing

The structure of PAN AIR is arranged so that the final output data can be extracted from the system either at the time of problem solution or at any time afterwards. A minimal data set required for all final configuration data extractions is generated by the MDG (Minimal Data Generator) module and placed on the MDG Data Base. (All data bases are automatically saved unless purged by the user.) In subsequent post-processing, the MDG data base is used as a starting point to compute surface flow properties (velocities and pressure coefficients) and force and moment coefficients for all networks.

This arrangement allows the final data extraction to be isolated from the boundary value problem solution. It also allows multiple sets of data to be generated in which the several user options available with respect to network, solution, and surface selections, velocity corrections and pressure coefficient rules (see sections 2.1.6 and 2.1.7 above) can be varied. Thus, for example, complete sets of surface flow properties, generated using different pressure coefficient rules, can by obtained and compared.

### 2.3.5 Peripheral Plotting

The data generated in the post-processing operations described above can be printed by each of the post-processing modules concerned (PDP for surface flow properties and CDP for force and moment coefficients). This data and the geometry of all panel corner points can also be placed on appropriate data bases and used to set up standard format plot files for subsequent interactive graphics display or hardcopy plotting by user-supplied software routines. The process is initiated by submitting a "PLOT" command in the MEC data. This activates the Print-Plot Processor module (PPP) and opens the appropriate DQG, PDP and CDP data bases. The user then constructs a number of plotting "cases," each of which represents a separate plotfile. The information required to specify a plotting case consists of the type of data to be processed and selections from the previous defined computation case identifiers, solution identifiers and network identifiers. These plotfiles are then placed on tape and displayed using interactive graphics or flatbed plotter equipment.

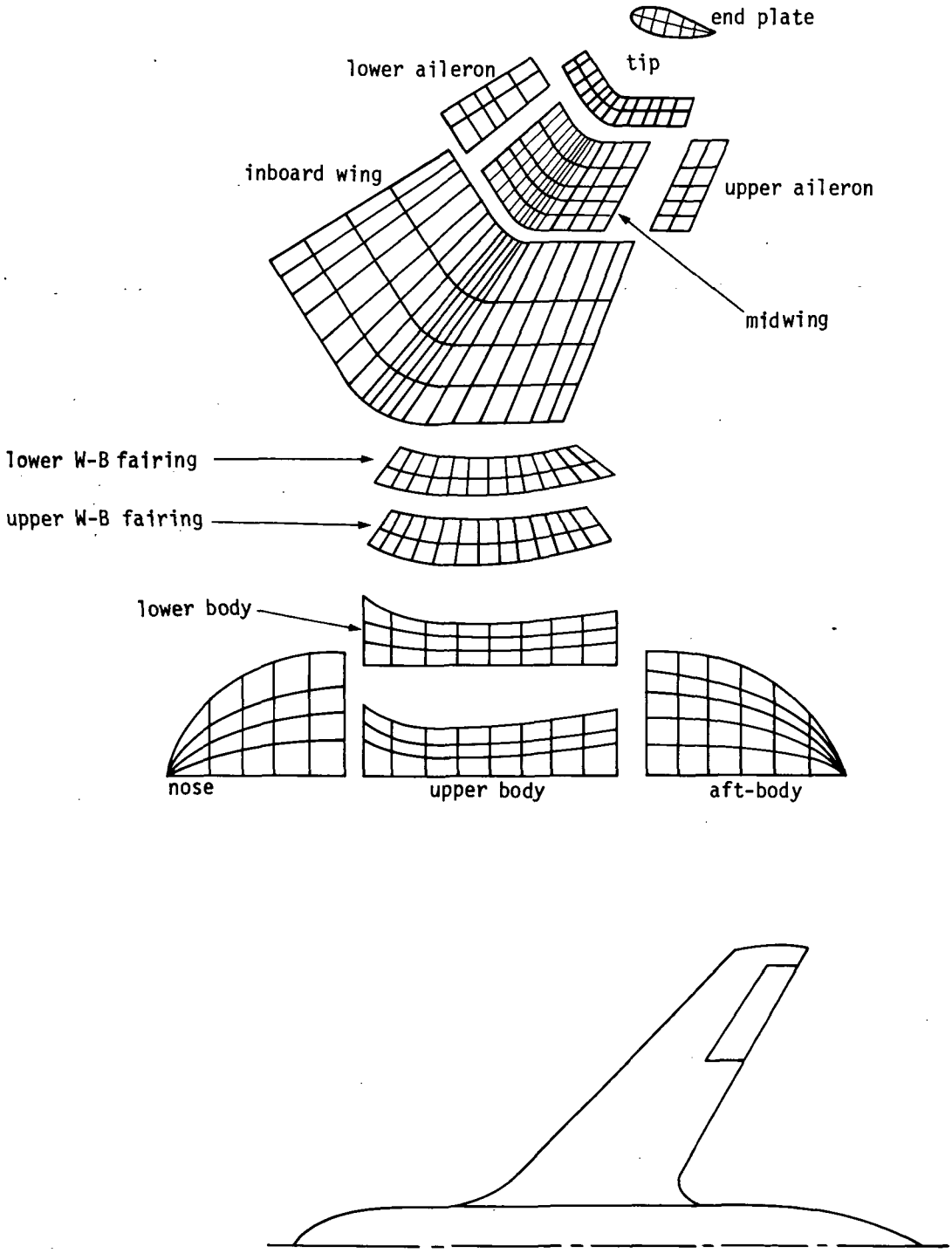
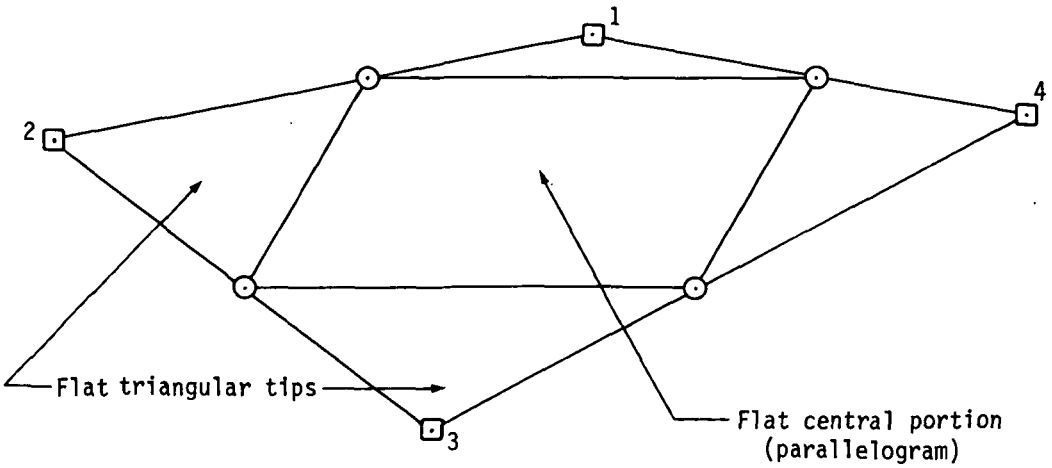



Figure 2.1 - Construction of a configuration from a set of networks

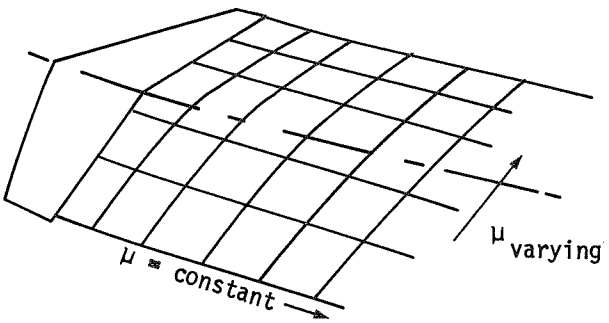



Corner points 1 and 3 are below the plane of the flat central portion
Corner points 2 and 4 are above the plane of the flat central portion

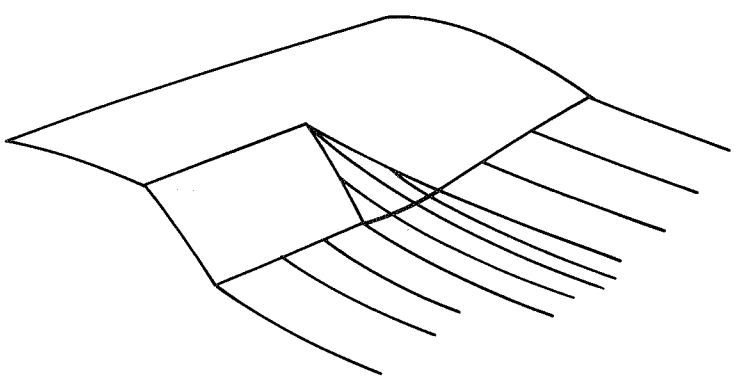
⊙ Panel edge midpoint

⊡ Panel corner point

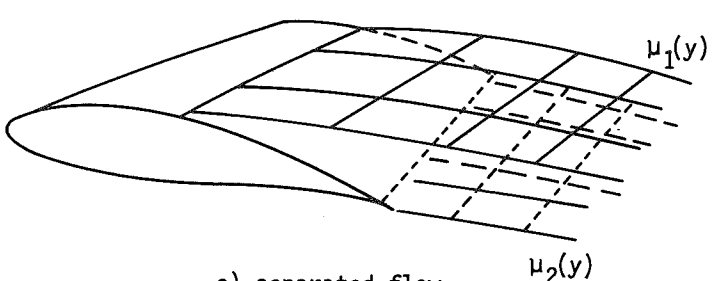
Figure 2.2 - General PAN AIR panel with flat central portion and four flat triangular tips.




a) simple wake



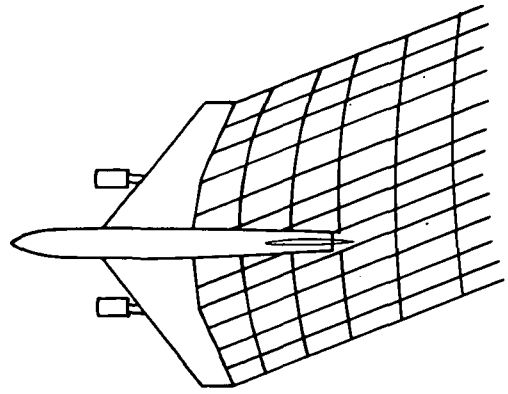
b) flapped configuration wake



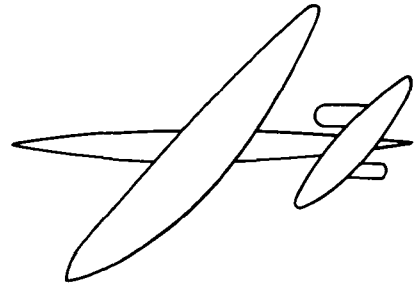

c) separated flow

(μ = doublet strength)

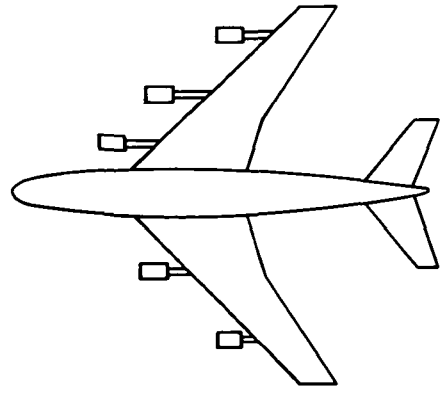
Figure 2.3 - Examples of use of wake networks



a) skewed wake simulation in sideslip

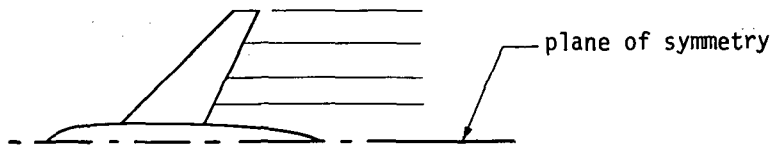


b) yawed wings

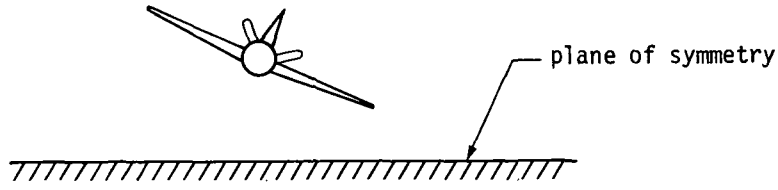


c) asymmetric stores or ferry engines

Figure 2.4 - Examples of configurations which must be treated as asymmetric



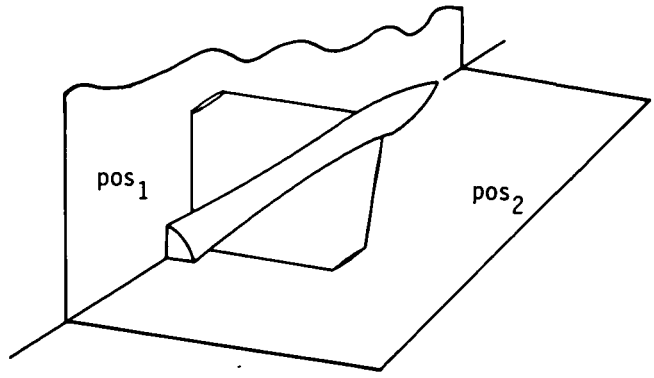

a) symmetric configuration



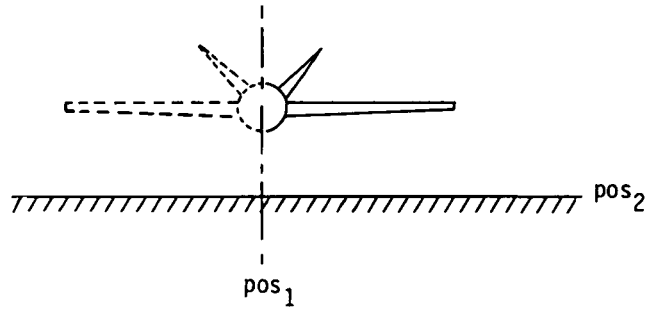

b) configuration in ground effect

Figure 2.5 - Examples of configurations which have one plane of symmetry

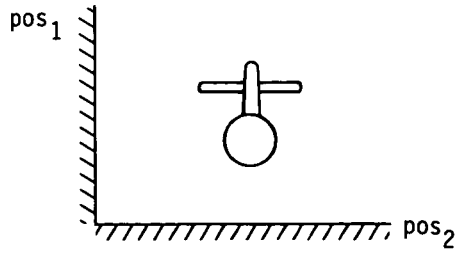
pos: plane of symmetry




a) two planes of configuration symmetry

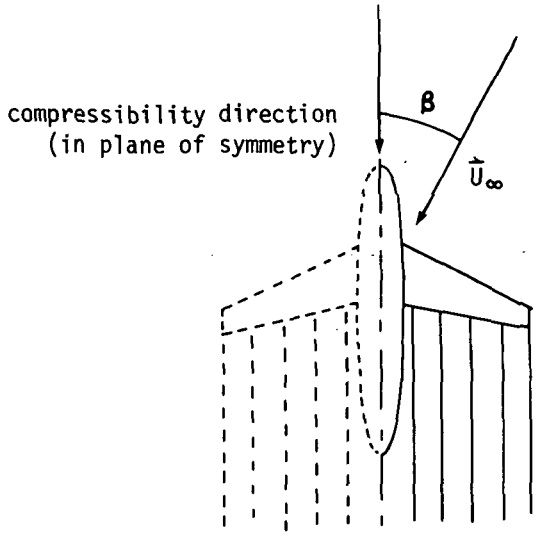



b) one plane of configuration symmetry in ground effect

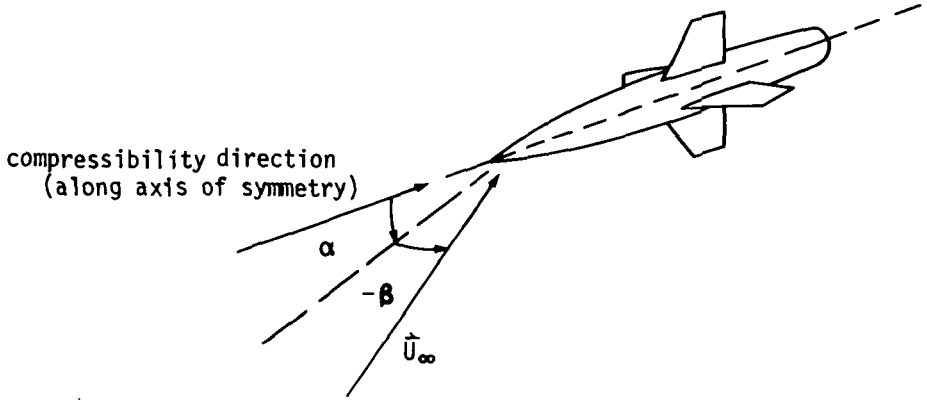



c) corner flow

Figure 2.6 - Examples of configurations which have two planes of symmetry

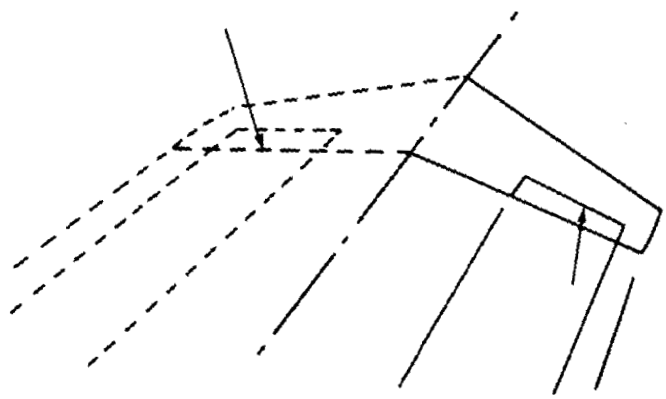



a) one plane of configuration symmetry

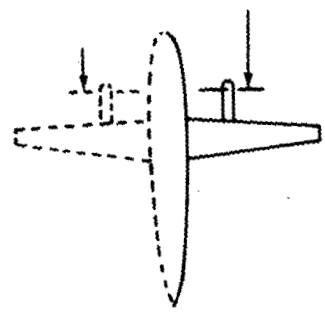



b) two planes of configuration symmetry

Figure 2.7 - Examples of asymmetric flow for symmetric configurations

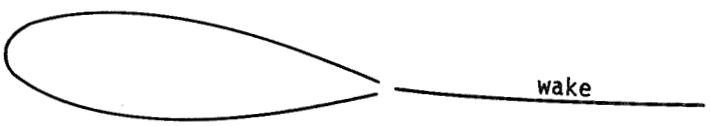


a) control surface deflections



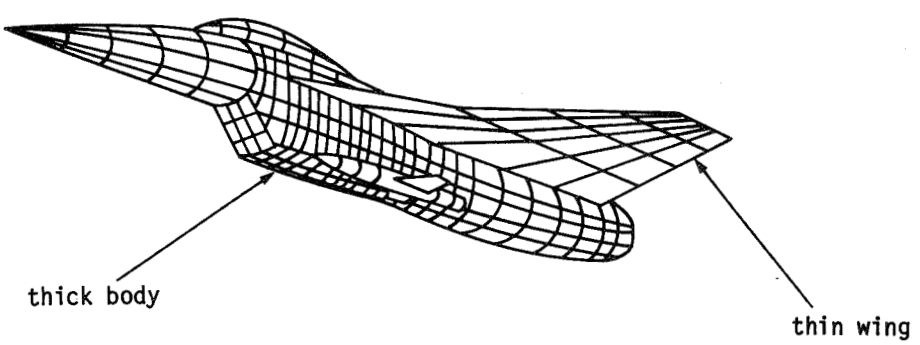
b) propeller disc modeling

Figure 2.8 - Examples of linearized asymmetric flow modeled through boundary conditions



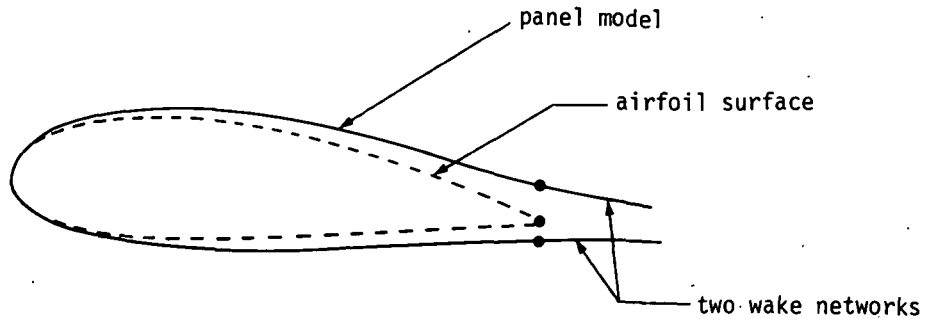

a) thick configuration

b) thin configuration



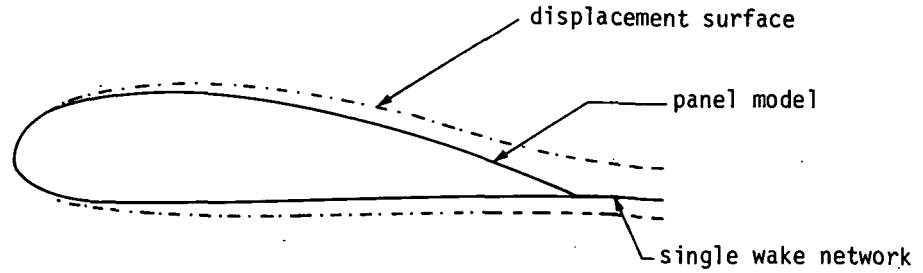

c) combinations

Figure 2.9 - Examples of thick and thin configuration modeling




a) exact modeling

- panels and boundary conditions on surface representing airfoil plus boundary layer (displacement modeling)



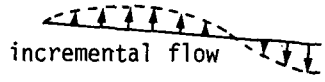

b) linearized modeling

- panels and boundary conditions on airfoil surface
- additional source distribution to represent boundary layer thickness

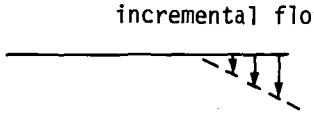
——— paneled surface

Figure 2.10 - Use of exact and linearized modeling of boundary layer displacement effects

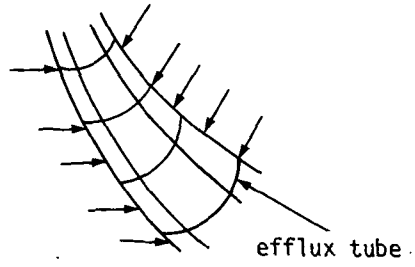
a) thickness with a thin surface representation




b) camber with a flat surface representation




c)incidence or surface deflection

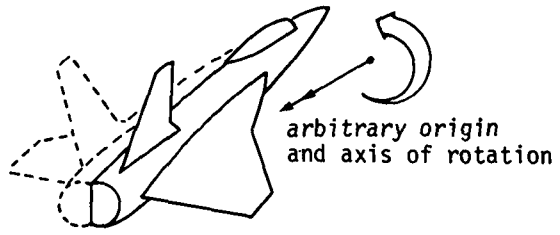



d) entrainment

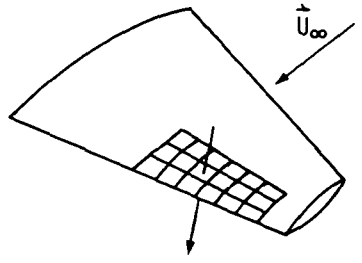
——— paneled surface

– – – – simulated surface

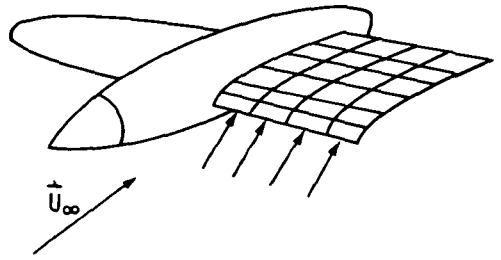
Figure 2.11 - Examples of linearized modeling




a) rotational onset flows - global rotation (quasi-steady)




b) local onset flows - network wide




c) local onset flows - each control point

Figure 2.12 - Examples of incremental onset flows

| | |
|---|---|
| Surface selection | - Upper (system default)<br>- Lower<br>- Uplo (upper minus lower)<br>- Loup (lower minus upper)<br>- Average |
| Point location | - Panel center control points (system default)<br>- Network edge control points<br>- Enriched grid points<br>- User-specified points |
| Velocity computation methods | - Boundary conditions (system default)<br>- Velocity influence coefficients |
| Velocity corrections | - None (system default)<br>- Duct flow correction<br>- Leading edge correction |
| Pressure coefficient rules | - Isentropic (system default)<br>- Linearized<br>- Second-order<br>- Reduced second-order<br>- Slender body |

Figure 2.13 - Surface flow properties - output options including system defaults

| | |
|---|---|
| Surface selection | - Upper (system default)<br>- Lower<br>- Uplo (upper plus lower) |
| Computation summation | - Panels<br>- Panels columns<br>- Network (system default)<br>- Configuration (system default) |
| Velocity computation methods<br>Velocity corrections<br>Pressure coefficient rules | - Same as for surface flow properties |
| Edge force | - No (system default)<br>- Yes |
| Axis systems | - Reference coordinate system (system default)<br>- Stability axis system<br>- Wind axis system (system default)<br>- Body axis system |
| Reference dimensions option | - No (system default)<br>- Yes |

Figure 2.14 - Forces and moments - output options including system defaults

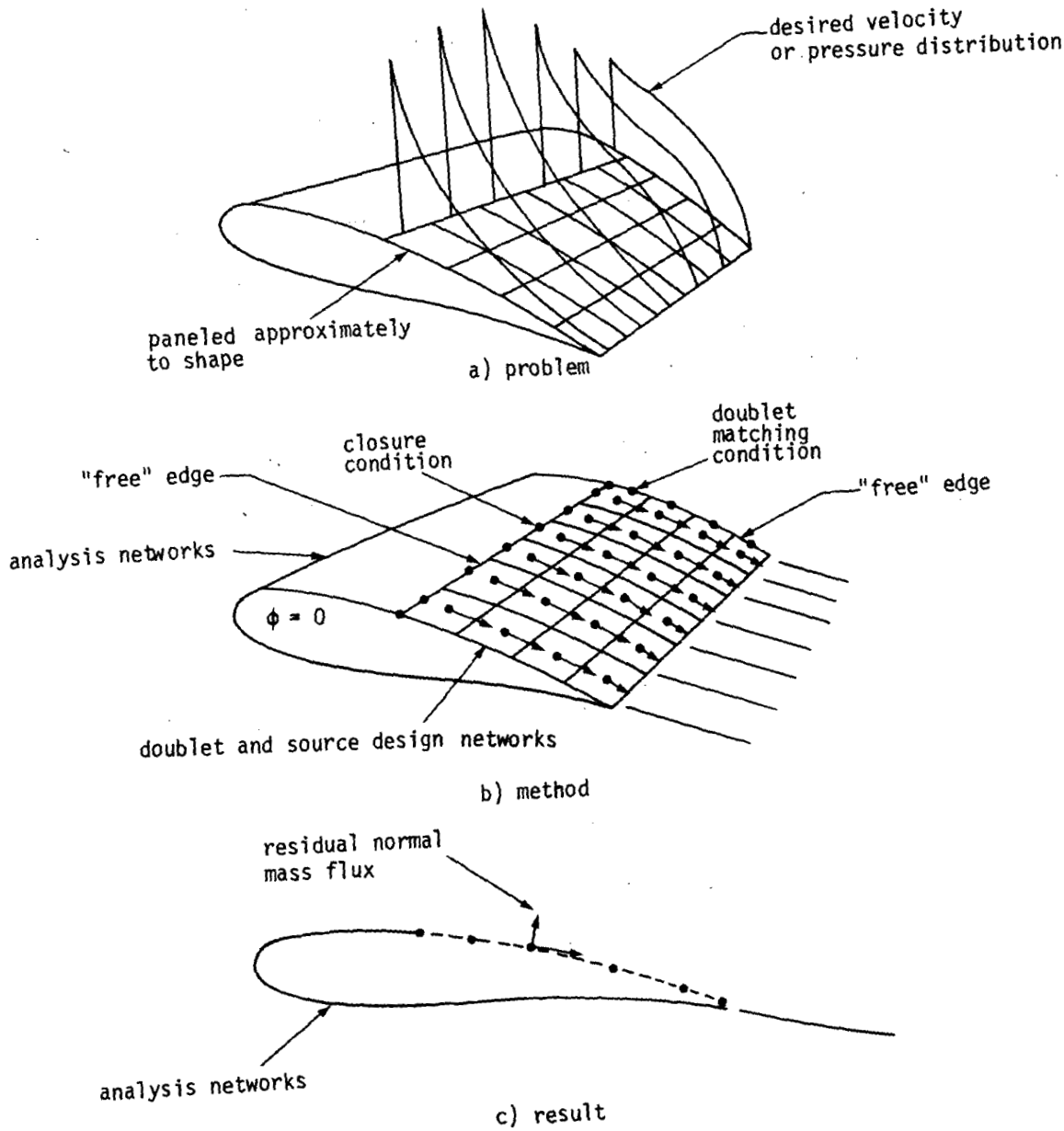



Figure 2.15 - Example of non-iterative design of thick configuration

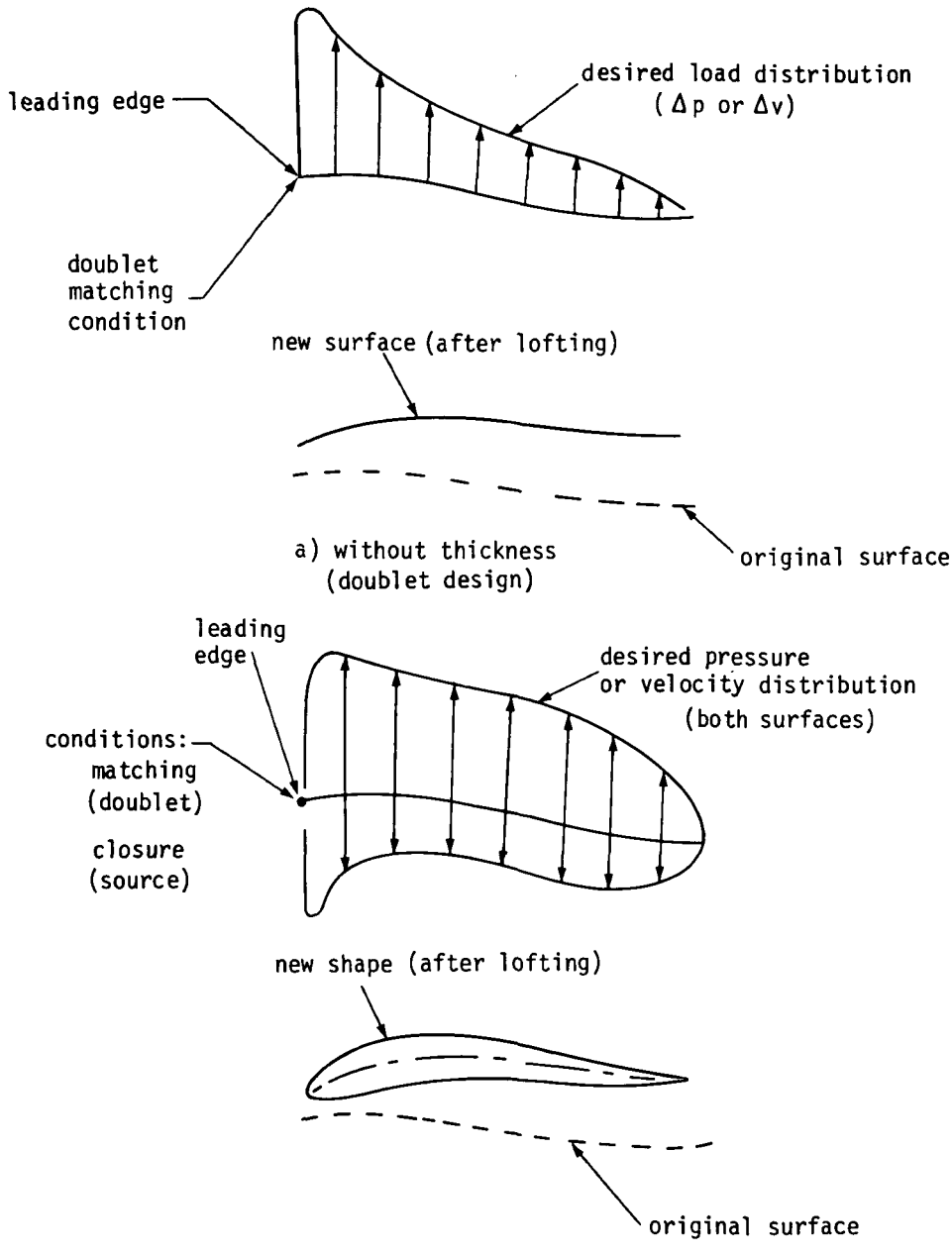



Figure 2.16 - Examples of non-iterative design of thin configurations

design (thick wing)

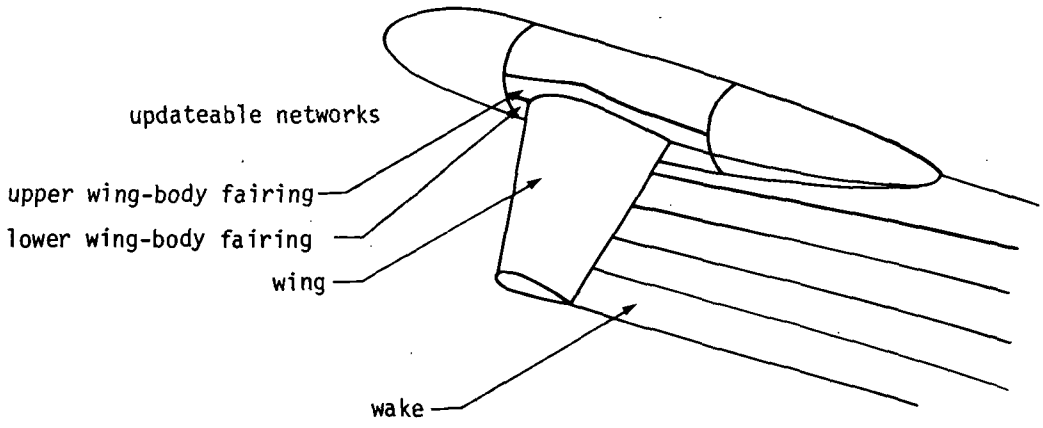
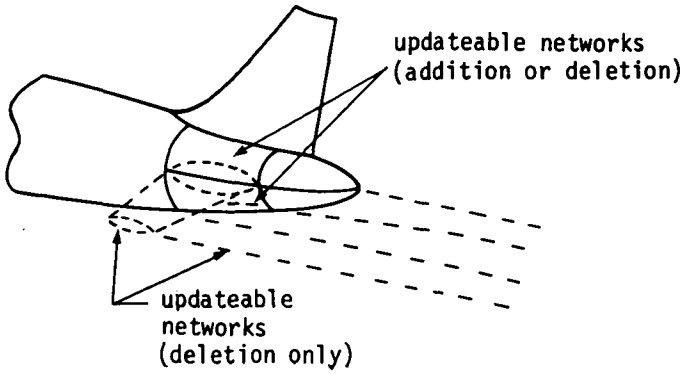
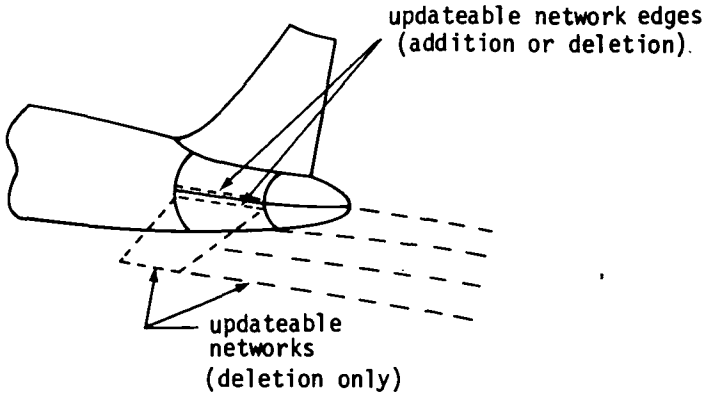



Figure 2.17 - Application of IC update capability - design

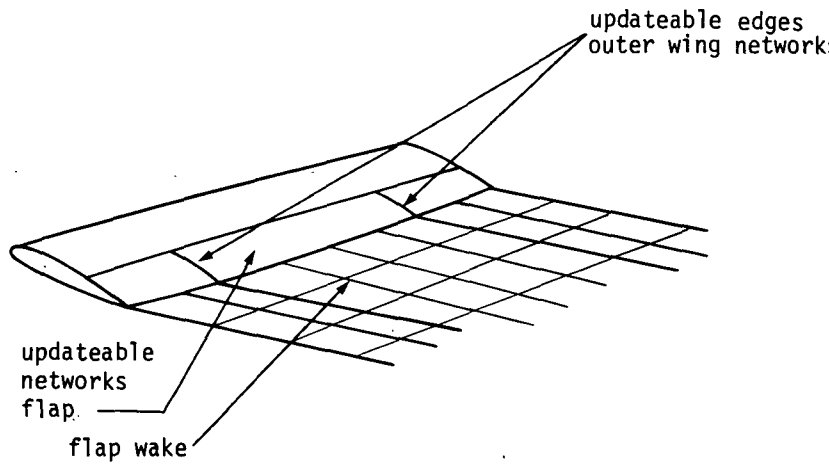



a) thick horizontal tail

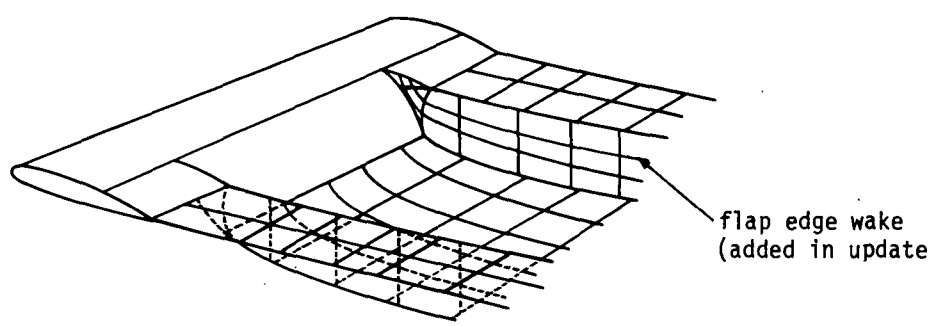



b) thin horizontal tail

Figure 2.18 - Application of IC update capability - network addition and deletion




a) original run




b) update run

Figure 2.19 - Application of IC update capability - successive control surface deflections

## 3.0 Beginner's Guide - Standard Aerodynamic Analysis Problems

In this section the engineering input data are described for the standard type of aerodynamic analysis problem (called class 1) that the user will encounter most often. The description covers the case of an "exact" representation of the configuration surface, as opposed to a "linearized" representation (see section 2.1.4). The user can specify the input data for this type of problem fairly easily without concern for the full capability, and the associated complexity, of the PAN AIR system.

It is recommended that the new user gain an initial familiarity with PAN AIR by running this type of problem first. Once an initial acquaintance with the program has been made, the user can begin to expand his interests to encompass the full capabilities of the PAN AIR system. Section B.3 provides the information necessary to set up and process the more complex cases. There the reader will find the possible boundary value problems divided into five classes. These allow the user to specify boundary condition equations and the associated input data in a convenient manner for a great variety of problems.

In the following the general structure of the PAN AIR input deck is described first. The general procedures for configuration modeling are then discussed, including the specification of physical and wake boundaries by network arrays of panels. Then the subclasses of the class 1 boundary conditions are discussed in detail. Finally, a sample problem with class 1 boundary conditions is discussed.

### 3.1 Structure of Input Deck

A complete deck for a PAN AIR run consists of three parts, each separated by an end-of-record card as shown in figure 3.1. The first part consists of a set of limited job control language (JCL) necessary to initiate execution of PAN AIR. The second part consists of the user directives to the MEC (Module Execution Control) module. The third part consists of the user supplied engineering data to define the problem to the DIP (Data Input Processor) module.

The user supplied JCL necessary to initiate execution of the PAN AIR system is very limited and simple. To execute PAN AIR on a computer installation having a catalogued procedure capability, the user needs only to have the required preliminary control cards (job name, user name, accounting information, and so forth) and then to access and execute a catalogued procedure created during installation of PAN AIR.

The MEC input data allows the user to identify the operating system, to specify identification names for the data bases and to specify the type of run to be executed through PAN AIR. The MEC module generates the control cards required to solve the problem.

The DIP module reads the basic engineering data, performs a few data checks and other calculations, and generates a data base for passing the input data on to the other modules. The DIP input data is divided into five data groups. In the Global Data Group the user specifies basic conditions of the

flow problem and can change some program default options. In the Network Data Group the user specifies the geometry and boundary conditions for each network. In the Geometric Edge Matching Data Group the user can specify abutments between network edges (as an alternative to an automatic program abutment procedure). The Flow Properties Data Group has two subgroups: in the Surface Flow Properties Data Subgroup the user specifies calculation of velocities and pressure coefficients on identified networks; in the Forces and Moments Data Subgroup the user specifies calculation of force and moment coefficients on identified networks. In the Print-Plot Data Group the user can specify the creation of data files suitable for subsequent printing and plotting.

In the Global Data Group the user specifies one or more "solution" data sets. These are combinations of onset flow properties, for example, angles of attack $\alpha$ and sideslip $\beta$. In the Flow Properties Data Subgroup and the Forces and Moments Data Subgroup the user specifies independent "cases" for the sets of calculations. For each case the user can select one or more solutions from the set originally specified in the Global Data Group.

The present section, particularly the example problem, is restricted to the program options and capabilities that are needed for a standard (class 1) aerodynamic analysis problem. The full capabilities of the PAN AIR system are discussed elsewhere. The full details of the JCL appear in section 5. The full details of the MEC data appear in section 6. The full details of the DIP data appear in section 7. This includes a complete description of all DIP records and a list of the options available for each record.

## 3.2 Configuration Modeling

The surfaces of both the physical and the wake configurations are defined by user-specified networks. Each network is defined by a rectangular array of grid points which define quadrilateral (or in special cases triangular) panels.

The division of the configuration into networks is somewhat arbitrary. It is restricted by rules which are described in section B.1.1. The basic rule is that a network should generally correspond to a physically meaningful part of the total configuration.

The indexing scheme used for networks is based on the user-defined rectangular array of grid points which are the corner points of the quadrilateral panels. The network size is defined by the numbers of rows (M) and columns (N) of grid points. Using the input grid points, PAN AIR defines (M-1) rows and (N-1) columns of panels. The identification of the rows and columns, and the network edge indexing scheme follows from the order in which the array of grid points is specified. The first column corresponds to the first set of grid points that are input, that is, points 1 through 3 in figure 3.2. This first column of (three) points also defines the (three) rows of the array. The second column of points is then input in the order of the rows, and so forth until the array is complete. The resulting alignment of the rows and columns, the indexing of the network edges, and the indexing of the (six) panels are illustrated in figure 3.2. The ordering of the user-specified grid points can be interpreted as follows: the first column of points forms network edge four, being ordered from network edge one to network edge three. The other columns of points are input in the same order, with the last column forming network edge two.

The direction of increasing row numbers is called the $\bar{M}$ direction and the direction of increasing column numbers is called the $\bar{N}$ direction (figure 3.2). The direction $\bar{N}x\bar{M}$ defines the positive direction of the network and panel unit normal vectors $\hat{n}$. This in turn defines the "upper" and "lower" surfaces of the network, with the convention that the normal vector points outward from the upper surface. This definition is very important since PAN AIR requires the specification of boundary conditions on both the upper and lower surfaces of the network, and the program output is identified by upper and lower surface labels. The network upper surface can also be determined in the following manner: if the viewer looks at the upper surface, figure 3.2 for example, then the network edge indices are in a counter-clockwise order; the normal vector points toward the viewer.

## 3.3 Impermeable Surface Mass Flux Analysis (Class 1) Boundary Conditions

This class of boundary conditions is the basic aerodynamic analysis problem for an impermeable surface. In the PAN AIR formulation the corresponding boundary condition is that of no mass flux flowing through the surface, or equivalently a zero value of the total mass flux component normal to the surface.

### 3.3.1 General Properties

The total mass flux is the sum of the total onset flow velocity and the perturbation mass flux, that is,

$$\vec{W} = \vec{U}_0 + \vec{w} \tag{3.3.1}$$

In the standard case the total onset flow velocity $\vec{U}_0$ is equal to the uniform onset flow velocity $\vec{U}_\infty$ specified by the speed of the freestream flow and by the angles of attack $\alpha$ and sideslip $\beta$. In general the total onset flow can also include contributions from a rotational onset flow and local onset flows, as described in section B.2.2.

For incompressible flow, the perturbation mass flux is equal to the perturbation velocity; the mass flux boundary condition is then equivalent to that of zero normal velocity at the surface. The reason mass flux, rather than velocity, boundary conditions are used for standard analysis problems is discussed in sections 5.4 and B.0 of the Theory Document. Mass flux boundary conditions are described further in sections B.3.2 of this document. Velocity boundary conditions can be specified in PAN AIR by using class 4 or class 5 boundary conditions, see section B.3.1.

For class 1 boundary conditions for non-wake networks there are two boundary condition equations. The first equation specifies the source strength directly. This equation is applied only at the control points at each panel center. The second boundary condition equation is also applied at the control points at each panel center. At the control points located on the network edges only one equation is applied: either the second boundary condition equation or a condition of doublet strength matching with abutting network edges. The latter condition assures continuity of doublet strength at network edges. The above process occurs automatically when the user has specified that class 1 boundary conditions are to be used.

### 3.3.2 Subclasses

The class 1 boundary conditions are grouped into five subclasses which are listed in table 3.1 (also figure 7.4). The boundary conditions are applied to three types of configurations: thick bodies (subclasses 1 and 2), thin bodies (subclass 3), and wakes (subclasses 4 and 5). The boundary condition equations are described below for each subclass. The equations for subclasses 1 through 3 are special cases of those used in the corresponding subclasses of class 2 boundary conditions, "Specified Normal Mass Flux Analysis", which are described in section B.3.2. An extended discussion of the mathematical properties and the pitfalls related to specification of boundary conditions, particularly when one singularity strength is specified directly, is given in section A.3.

#### 3.3.2.1 Class 1 - Subclass 1 (UPPER)

This boundary condition subclass is for an impermeable surface of a thick configuration in which the network's upper surface is exposed to the external flow field. This situation corresponds to the bottom network of figure 3.3. The boundary condition equations used by the program are

$$\sigma = -\vec{U}_0 \cdot \hat{n} \tag{3.3.2a}$$

$$\phi_L = 0 \tag{3.3.2b}$$

where $\sigma$ is the source strength and $\phi_L$ is the perturbation velocity potential at the lower surface of the network. It is shown in section B.3.2 that the boundary condition equations (3.3.2a) and (3.3.2b) are equivalent to the condition of zero total mass flux normal to the upper surface.

This boundary condition subclass produces the condition of flow parallel to a surface enveloping a nonphysical domain of finite volume. For subsonic flows the configuration surface (formed from one or more networks) must be, strictly speaking, closed as demanded by existence and uniqueness requirements of the Prandtl-Glauert equation. Thus the surface can have no "holes". Details such as wing tips must be closed by panels. (In practice it is sometimes possible to have small holes in a surface which cause only localized distortion of the flow field in subsonic flow.)

#### 3.3.2.2 Class 1 - Subclass 2 (LOWER)

This boundary condition subclass is the counterpart of subclass 1 and is used when the lower surface of a network of a thick configuration is exposed to the external flow field. The top network of figure 3.3 illustrates this situation. The boundary condition equations used by the program are

$$-\sigma = -\vec{U}_0 \cdot \hat{n} \tag{3.3.3a}$$

$$\phi_U = 0 \tag{3.3.3b}$$

| Subclass* | Subclass Description |
|---|---|
| 1 - UPPER | Impermeable Upper Surface |
| 2 - LOWER | Impermeable Lower Surface |
| 3 - AVERAGE | Impermeable Average (Cambered) Surface |
| 4 - WAKE 1 | Wake 1 (with spanwise variation of doublet strength) |
| 5 - WAKE 2 | Wake 2 (with constant doublet strength) |

* Program Index-Keyword

Table 3.1 Subclasses for class 1 boundary conditions

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The sign difference between equations (3.3.2a) and (3.3.3a) follows from the interchange of the upper and lower surfaces.

3.3.2.3 Class 1 - Subclass 3 (AVERAGE)

This boundary condition subclass is the condition of zero total normal mass flux on both the upper and lower surfaces of a thin ("average") configuration as shown in figure 3.4. The boundary condition equations used by the program are

$$\sigma = 0 \tag{3.3.4a}$$

$$\vec{w}_A \cdot \hat{n} = -\vec{U}_o \cdot \hat{n} \tag{3.3.4b}$$

where $\vec{w}_A = 1/2\ (\vec{w}_U + \vec{w}_L)$ is the average (of the upper and lower surface values) perturbation mass flux at a control point.

3.3.2.4 Class 1 - Subclass 4 (WAKE 1)

This boundary condition subclass is used for wake networks (type DW1 in program notation) which are placed behind lifting surfaces (or wake networks of the same type). The subclass gives the boundary condition equations of (1) zero source strength, and (2) doublet strength matching at the specified edge of the wake network and the abutting edge of the lifting surface. For type DW1 networks the doublet strength can vary in the spanwise direction but is

constant in the (nominally) streamwise direction. These properties cause the Kutta condition to be satisfied at subsonic trailing edges of lifting surfaces. An example of application of a type DW1 network and the subclass 4 boundary condition is shown in figure 3.5.

The wake network of type DW1 has control points located along only one edge. These allow the doublet strength matching with the abutting edges of the upstream network(s). The control points are located on edge 1 of a type DW1 network; thus the user inputs the DW1 grid points so that the M-direction points downstream. Also, it is good modeling practice to having compatible paneling of the wake and the upstream networks at the abutting edge.

#### 3.3.2.5 Class 1 - Subclass 5 (WAKE 2)

This boundary condition subclass is used for wake networks (type DW2 in program notation) which are used to obtain continuity of wake surfaces. The subclass gives the boundary condition equations of (1) zero source strength, and (2) constant doublet strength throughout the network. A network with these boundary conditions is generally located downstream of a non-lifting surface or located spanwise either between a fuselage and a wake of a lifting surface or between two wake networks. The constant doublet strength is determined by a matching condition with an abutting wake network.

An application of the type DW2 wake network and the associated subclass 5 boundary condition is shown in figure 3.6. Edge 1 of the DW2 network abuts a non-lifting surface; edge 4 abuts an adjacent wake network; edge 2 abuts the image of the DW2 network in the plane of configuration symmetry. The DW2 network has a single control point (located at the corner of edges 1 and 4) which is used to match the doublet strength with the abutting network.

## 3.4 Example for Class 1 Boundary Conditions

An example of the aerodynamic analysis of a simple configuration shown in figure 3.7 is described. A complete listing of the input data is given in figures 3.8 and 3.9. The input data occurs in three blocks (figure 3.1) which are: the control cards and JCL, the MEC input data, and the engineering input data which is read by the DIP (Data Input Processor) module of PAN AIR.

### 3.4.1 Control Cards and JCL

This block of data consists of four control cards as shown in figure 3.8. The first is the job card and the second is the user card. The form of these two control cards depends on the operating system of the computer installation. The other two control cards are necessary to initiate a PAN AIR run. These cards access and execute a catalogued JCL procedure file stored with the PAN AIR software system. This JCL procedure file accesses and executes the MEC module and the control cards generated by MEC.

In this block of data the user specifies the type of problem to be run. The MEC module interprets the given input data and performs several functions: supplies most of the job control cards (JCL) required to solve the problem, specifies the required data bases, and processes some computing system information.

An example containing a limited set of MEC input data is shown in figure 3.8. The first card identifies the PAN AIR system. The second card identifies the computer operating system. The third card is a run identification title used to identify the output. The next seven cards specify the data base information, including all identifications required for the data bases. The next to last card instructs PAN AIR to use the capability to check the DIP module input data before executing the regular solution. The last card indicates the end of the MEC data. It is noted that there is no instruction on the type of solution since a regular potential flow solution is being requested, which is the default option. For details refer to section 5.

### 3.4.3 General Information for DIP Module

The complete input data for the DIP module are described in section 7; only the input records and options needed for a standard aerodynamic analysis problem are described in the present section.

The DIP input records are of three basic types. First, an instruction record consists of a "primary keyword" which identifies the instruction being specified. Second, an instruction-parameter record consists of a primary keyword, followed by an equal sign, followed by one or more "secondary keywords" which specify particular options, or by a user-supplied name, or by numerical data, or by a combination of the three. Third, a data record consists of numerical data only.

In most cases one DIP input record is one 80 character computer card. If an input record is particularly long, it can be continued onto several cards: "record continuation" is indicated by a plus (+) as the last character on a card. Record continuation is usually not required for data records.

User comments can be included in the DIP input data in either of two formats. Cards beginning with the two symbols */ are comment cards, which are ignored by the DIP module. Also, the symbol / is an optional terminator for input records; all information after this symbol is ignored.

A default is the instruction, option, or data assigned by the DIP module when the user omits part or all of an input record. In PAN AIR many of the records associated with specialized features or applications have defaults designed for standard cases. In the present case several of the DIP input records shown in figure 3.9 could have been omitted; these are labeled DEFAULT in the input listing.

### 3.4.4 Configuration

For the example of an aerodynamic analysis problem, the configuration is a triangular delta wing with a double wedge symmetric airfoil section, figure 3.7. The configuration is modeled by three networks: one for the top of the wing, one for the bottom of the wing and one for the wake. The boundary conditions on the wing networks are class 1 and either subclass 1 or 2, depending on whether the upper or lower surface of the network is exposed to the external flow.

The input data, primarily the configuration geometry, are specified in the reference coordinate system. The PAN AIR implied reference coordinate system is used: $x_0$ positive aft, $y_0$ positive right and $z_0$ positive up on the configuration. The compressibility coordinate system is specified to coincide with the reference coordinate system (see section B.2.1). The flow is supersonic at Mach 2.0. The uniform onset flow speed is specified to have a unit value; this can be done since the Prandtl-Glauert equation is linear.

### 3.4.5 DIP Input Data

The input data for the DIP module are listed in figure 3.9. The identifying numbers of the records used for the example configuration are included as comments. (A list of identifying numbers and names of all PAN AIR records is given in section 7.2.2.) Individual records are organized by data groups; the records are described in sections 7.3 to 7.7. The function of each record listed in figure 3.9 is described below.

Record G1. This record identifies the start of the Global Data Group, which specifies global conditions of the problem, such as possible symmetries, compressibility data and solution data. The records can also specify default options for subsequent calculations, but these are mostly deferred to the Flow Properties Data Group in the present example.

Record G2. This record gives the problem identification (PID) title.

Record G3. This record gives the user identification (UID) title.

Record G4. This record specifies the configuration and flow symmetries. In this example there is one plane of configuration symmetry (FIRST-PLANE), with normal vector parallel to the $y_0$ -axis (components 0. 1. 0.) and located at the origin (coordinates 0. 0. 0.); the flow may be asymmetric (ASYMMETRIC-FLOW) with respect to the plane of configuration symmetry. Since the configuration is symmetric with respect to the $x_0$ -$z_0$ plane, only the $y_0 \geq 0$ half of the configuration is input (record sets N2).

Record G5. This record specifies the compressibility data. The Mach number of the uniform onset flow is 2.0. CALPHA and CBETA are angles (in degrees) specifying the transformation between the reference and the compressibility coordinate systems (see section B.2.1). With zero values for the two angles, these two coordinate systems coincide and Mach cones are centered about axes parallel to the $x_0$-axis.

Record Set G6. This record set specifies the "solution" data. The first record identifies the quantities specified: angle of attack (ALPHA), angle of sideslip (BETA), uniform onset flow velocity (UINF), and an alphanumeric solution identification name (SID). The next two records specify the data for two solutions. The first solution has one degree angle of attack and a unit uniform onset flow velocity. The second solution has one degree angle of sideslip and a unit uniform onset flow velocity. (PAN AIR will solve the flow problems for all specified solutions. The user can select subsequently from these solutions when specifying post-solution calculations of surface flow properties and/or forces and moments.)

Record G7. This record specifies a tolerance distance of .001 for the automatic geometric edge matching process. If any network edges are separated by an amount less than this tolerance distance, a network edge abutment is automatically defined and the doublet strength matching condition is applied to the edges in the abutment (see section B.3.5).

Record N1. This record identifies the start of the Network Data Group, which specifies the geometric and boundary condition data for the independent networks. (In the present configuration there are three networks.)

Record Set N2. This record set specifies the first network, which represents the top half of the wing. Record N2A identifies the network data, gives the user-specified alphanumeric network identification name (WING-TOP), and specifies the panel array as having 3 rows and 4 columns of grid points (thus 2 rows and 3 columns of panels). Record N2B gives the coordinates of the 12 grid points; figure 3.7 shows the network planform and the grid point ordering. The first column of points was (arbitrarily) chosen to be at the wing root, and the points are entered in the direction of increasing $x_0$; this defines the $\bar{M}$-direction shown in figure 3.7. The second, third, and fourth columns of points are entered in the same fashion, moving from root to tip and thus defining the $\bar{N}$-direction. Note that there are three grid points input at the pointed tip, even though they have identical coordinates (1.5, 1.5, 0.0). The positive unit normal is in the direction of $\bar{N}x\bar{M}$ and thus points downward into the interior, nonphysical flow field enclosed by the wing boundary. Thus the lower surface of the network is exposed to the physical flow field.

Record N9. This record specifies the boundary condition: class 1, subclass LOWER (or 2). Since the input grid array defines the network surface normal vector as pointing downward, the lower surface is exposed to the external flow field. Thus subclass LOWER boundary conditions are required for this network.

Record Set N2. This record set specifies the second network, which represents the bottom half of the wing. Record N2A gives the user-specified alphanumeric network identification name (WING-BOTTOM), and specifies the panel array as having 3 rows and 4 columns of grid points. Record N2B gives the coordinates of the 12 grid points, see figure 3.7. These grid points are entered in the same order as for network WING-TOP. Thus the normal vector points downward, which for the present network is pointing into the physical, external flow field (see figure 3.7). Thus the upper surface of the network is exposed to the physical flow field.

Record N9. This record specifies the boundary condition: class 1, subclass UPPER (or 1). Since the input grid array defines the network surface normal vector as pointing downward, the upper surface is exposed to the external flow field. Thus subclass UPPER boundary conditions are required for this network.

Record Set N2. This record set specifies the third network, which represents the wing wake. Record N2A gives the user-specified alphanumeric network identification name (WING-WAKE), and specifies the panel array as having 2 rows and 4 columns of grid points. Record N2B gives the coordinates of the 8 grid points, see figure 3.7. The ordering of the grid points results in the leading edge being edge number 1. Thus the wake network control points are in the correct position. (In the present case with a supersonic wing trailing edge, the length of the wake network is not important.)

Record N9. This record specifies a class 1, subclass WAKE 1 (or 4) boundary condition since the wake network is type DW1. This type allows spanwise (but not streamwise) variation of the doublet strength which in turn allows trailing vorticity to be shed from the wing.

Comment: The specified configuration is closed as required by good modeling practice. At this point two solutions and three networks have been specified. In the subsequent records, the solutions and the networks can be identified either by their alphanumeric identification names or by the corresponding integer indices defined by the program. The indices are assigned sequentially in the order in which the solutions and networks are input by the user. The names and indices are summarized in table 3.2.

Geometric Edge Matching Data Group. The records in this data group are omitted since all network edge abutments will be defined automatically. (All abutting edges coincide exactly and thus meet the geometric edge matching tolerance which was set to .001 in record G7.) The condition of doublet strength matching will be applied between the abutting edges.

Record FP1. This record identifies the start of the Flow Properties Data Group, which specifies options for several types of post-solution calculations, that is, calculations that occur after solution of equation (A.3.5) for the singularity strengths. The FP1 record is followed by one or more "cases" involving calculation of the surface flow properties (SF records) and/or forces and moments (FM records). In the present example there is one case of each type.

Record SF1. This record identifies a case of surface flow properties calculations. An alphanumeric case identification name (SF-CASE-A) is specified. This name or the corresponding integer index (see table 3.2) is used to identify the case in the output. All the following SF records are for this case.

Record SF2. This record identifies the networks for which surface flow properties are to be calculated for SF-CASE-A. The networks are (1) the network WING-TOP, both the input network (INPUT) and its image network (1ST) in the plane of symmetry, and (2) the network WING-BOTTOM, both the input network (INPUT) and its image network (1ST) in the plane of symmetry. The + sign on the first card indicates that the record is continued onto the second card.

| | ID Name | ID Index |
|---|---|---|
| Solutions | 1-DEGREE-ALPHA | 1 |
| | 1-DEGREE-BETA | 2 |
| Networks | WING-TOP | 1 |
| | WING-BOTTOM | 2 |
| | WING-WAKE | 3 |
| Surface Flow Properties Cases | SF-CASE-A | 1 |
| Forces and Moments Cases | FM-CASE-A | 1 |

Table 3.2 Solutions, networks and post-solution cases for example of figures 3.8 and 3.9

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Record SF3. This record tells PAN AIR to calculate the surface flow properties for both the 1-DEGREE-ALPHA and the 1-DEGREE-BETA solutions defined in record G6. This record could have been omitted since it specifies the default condition: all defined solutions.

Record SF4. This record tells PAN AIR to calculate the surface flow properties at ALL-CONTROL-POINTS of the networks (and images) specified in record SF2.

Record SF5. This record tells PAN AIR to calculate the flow properties on the UPPER and LOWER surfaces of the networks (and images) selected in record SF2. Since the lower surface of the WING-TOP network is exposed to the external flow field, the LOWER surface output for WING-TOP will give the velocities and pressure coefficients of physical interest. Similarly since the upper surface of the WING-BOTTOM network is exposed to the external flow field, the UPPER surface output for WING-BOTTOM will give the velocities and pressure coefficients of physical interest.

Comment: To simplify the interpretation of the surface flow properties (and forces and moments) output, it is good practice to have the same surface (say, UPPER) of each network exposed to the external flow. Then the physical flow properties will always be printed under the same heading. This can be done by choosing the directions of grid point input such that $\hat{n}$ (defined by $\bar{N}x\bar{M}$) always points into the exterior flow field. For example, the direction of $\hat{n}$ for the network WING-TOP can be reversed from that shown in figure 3.7 by entering the grid points from trailing edge to leading edge, root to tip; this reverses the direction of $\bar{M}$ (but not $\bar{N}$) so that the direction $\bar{N}x\bar{M}$ (and $\hat{n}$) is reversed, and the upper surface is exposed to the external flow field. The disadvantage of this approach is that it prevents one from using a consistent input ordering scheme. To avoid this conflict, PAN AIR provides the user with a REVERSE option on record SF2. When this option is specified, PAN AIR

reverses the upper and lower surface of the selected network(s) for calculations done by the PDP module (similarly with record FM8 for the CDP module). The REVERSE option does not affect program results computed prior to the PDP and CDP modules. For example, the unit normal $\hat{n}$, whose components are printed by the DQG module, is always in the direction of $\bar{N}x\bar{M}$, whether or not the REVERSE option is used. Similarly, the proper choice between subclass 1 and 2 boundary conditions is still based on the original (that is, unreversed) upper and lower surfaces defined by $\bar{N}x\bar{M}$. The REVERSE option is illustrated by the force and moment case (FM records) which follows the SF records.

Record SF6. This record specifies the method used for the velocity computations. In this case the velocities are to be calculated from the boundary conditions, see section B.4.1. This record could have been omitted since it specifies the default condition.

Record SF7. This record specifies the option used in the computation of the pressure. In the present example the approximate pressure coefficient rules will use the UNIFORM-ONSET-FLOW direction (defined by ALPHA and BETA, record G6) in defining the first order perturbation velocity component for each solution, see section B.4.2. This record could have been omitted since it specifies the default condition.

Record Set SF10. This record set specifies the quantities to be printed by the PDP module and is also used to select two associated computation options. Record SF10A specifies ALL available printout options, see table 7.9. Record SF10B specifies that no (NONE) velocity correction will be used, see section B.4.1. This record could have been omitted since it specifies the default condition. Record SF10C specifies that the ISENTROPIC and LINEAR rules be used in computing the pressure coefficients, see section B.4.2.

Record FM1. This record tells PAN AIR that one or more "cases" of forces and moments calculations are to be run. (It also indicates completion of the input data for the previous surface flow properties case.)

Record FM3. This record specifies the axis systems in which the force and moment coefficients are to be expressed in the output. Two axis systems are specified: the reference coordinate system (RCS), and the wind axis system (WAS) which is defined from the reference coordinates by rotations of (minus one times) the angles of attack and sideslip for each solution. In both systems the moment reference point is the origin (coordinates 0. 0. 0.). This record could have been omitted since it specifies the default condition.

Record FM4. This record tells PAN AIR to compute the force and moment coefficients for both the 1-DEGREE-ALPHA and the 1-DEGREE-BETA solutions defined in record G6. This record could have been omitted since it specifies the default condition: all defined solutions.

Record FM5. This record specifies the options for the force and moment coefficients to be (calculated and) printed. The force and moment coefficients for each column (COLSUM) of panels for each specified network are to be printed; the quantities are to be expressed in the reference coordinate system (RCS) only. Also, the force and moment coefficients for each specified network (NETWORK) and for the configuration of networks (CONFIGURATION) specified (by record FM8) in each "case" are to be printed; the quantities are to be expressed in all coordinate systems specified in record FM3. This record could have been omitted since it specifies the default condition.

Comment: The preceding FM records establish general conditions, including several defaults, for the "cases" of forces and moments calculations specified in the subsequent records.

Record FM7. This record identifies one case of forces and moments calculations. An alphanumeric case identification name (FM-CASE-A) is specified. This name or the corresponding integer index (see table 3.2) is used to identify the case in the output. The following FM records are for this case.

Record FM8. This record identifies the configuration for which force and moment coefficients are to be calculated for FM-CASE-A. The configuration consists of (1) the network WING-TOP, both the input network (INPUT) and its image network (1ST) in the plane of symmetry, with the instruction to REVERSE the normal vector (and thus reverse the identification of the upper and lower surfaces for this network), and (2) the network WING-BOTTOM, both the input network (INPUT) and its image network (1ST) in the plane of symmetry. The + symbol on the first card indicates that the record is continued onto the second card.

Record FM12. This record tells PAN AIR to calculate the force and moment coefficients on the UPPER surface for each of the networks (and images) selected in record FM8. Since the normal vector of the WING-TOP network has been reversed for this case by record FM8, the UPPER surface of both networks is exposed to the external flow field and will give the force and moment coefficients of physical interest. This record could have been omitted since it specifies the default condition.

Record FM13. This record specifies the method used for the velocity computations. In this case the velocities are to be calculated from the boundary conditions, see section B.4.1. This record could have been omitted since it specifies the default condition.

Record FM14. This record specifies the option used in the computation of the pressure. In the present example the approximate pressure coefficient rules will use the UNIFORM-ONSET-FLOW direction (defined by ALPHA and BETA, record G6) in defining the first order perturbation velocity component for each solution, see section B.4.2. This record could have been omitted since it specifies the default condition.

Record FM15. This record specifies that no (NONE) velocity correction will be used, see section B.4.1. This record could have been omitted since it specifies the default condition.

Record FM16. This record specifies that the ISENTROPIC and LINEAR rules will be used in computing the pressure coefficients, see section B.4.2.

Final Record. This record indicates the completion of the DIP input data. (It also indicates completion of the input data for the previous forces and moments case.)

Alternative. The present example allows an alternative way of defining the geometric configuration. The configuration has two planes of symmetry although only one plane (the $x_0$-$z_0$) is specified in record G4. If the second plane (the $x_0$-$y_0$) were also specified, then the input data for the WING-BOTTOM

network would be omitted. That network would be automatically defined by reflection in the second plane of symmetry. The resulting normal vector would be the reverse of that shown in figure 3.7, which also reverses the identification of the upper and lower surfaces for that network. Records SF2 and FM8 would have to be changed accordingly; the former WING-BOTTOM network would now be specified as additional images of the WING-TOP network.

### 3.4.6 Printed Output Data

The printed output from a standard PAN AIR run consists of two types of data. The first type is the checkout information which is printed by the MEC module and by the program modules (in the standard order of execution) DIP through MDG. The second type is the surface flow properties data printed by the PDP module, and the forces and moments data printed by the CDP module. These two types of printed output are described briefly below. In addition each module of PAN AIR generates data bases which may be accessed by the user. The PPP module allows the user to sort geometry data from the DQG module, surface flow properties data from the PDP module, and forces and moments data from the CDP module. These sets of data are sorted into a form which can be used by plotting programs (not part of PAN AIR) and can be printed by the user. This program feature is not described in the present example (see description of the PPP module output in section 8).

Checkout information is printed by each program. The MEC program always prints ("echos") its input data and prints some data base information. The other modules, DIP through MDG, print checkout information which is controlled by the user (record G17). In the present example the default option is used for the checkout prints, in which case each module will print warning messages, if any. (Error messages are always printed.) In addition the DIP module "echos" all of its input records. The DQG module will print various grid point, control point and network abutment data, which are identified in the printed output.

Some of the printed output from the PDP module is shown in figure 3.10. The first page, figure 3.10a, gives three user-supplied identification titles (one in the MEC data and two in the DIP data) and some general problem information specified by the user. The second page, figure 3.10b, describes the first case of calculated surface flow properties, including the options selected for the case in the surface flow properties data subgroup. This page is printed at the beginning of the data for each case.

The third page, figure 3.10c, and several similar subsequent pages show the requested flow quantities for the case. The heading information identifies the case, network, its image and orientation (RETAIN, that is, as input, or REVERSE). Several computation options selected by the user for this case are also identified. The flow properties are then printed for the requested points. The points (either control or grid points) are indexed in the manner of the "enriched (or fine) grid points," shown in the example of figure 3.11. The flow quantities are then listed. The flow quantities on both the upper and lower network surfaces are printed as requested in the example problem. Note that the flow properties on the upper surface are those of undisturbed flow, since the upper surface is not exposed to the physical flow field, figure 3.7, and thus has the perturbation stagnation boundary condition.

Some of the printed output from the CDP module is shown in figure 3.12. The first page, figure 3.12a, describes the first case of calculated forces and moments, including the options selected for the case in the forces and moments data subgroup. The second page, figure 3.12b, gives three user-supplied identification titles and some general problem information. The third page, figure 3.12c, gives additional information on the selected options, including descriptions of the selected axis systems for the force and moment coefficients: RCS (reference coordinate system) and WAS (wind axis system).

The fourth page, figure 3.12d, and several similar subsequent pages show the force and moment coefficients for the case. The heading information identifies the case, network, network image and orientation (REVERSE in this example). User-selected computation options are also identified. The force and moment coefficients are then printed for the requested panels, column of panels, networks, and configuration (which is the total for a case), for the requested axis systems and for the requested pressure coefficient rules. The panel and panel-column indexing scheme is shown in figure 3.2.

The information in figure 3.12 is repeated for all cases specified in the forces and moments data subgroup. In each case an accumulation record may be included which instructs the CDP module to add the force and moment coefficients (for only one set of computation options) to an accumulation total. If at least one accumulation is requested, then the accumulation total is printed as an additional case after the printed output for all other cases.

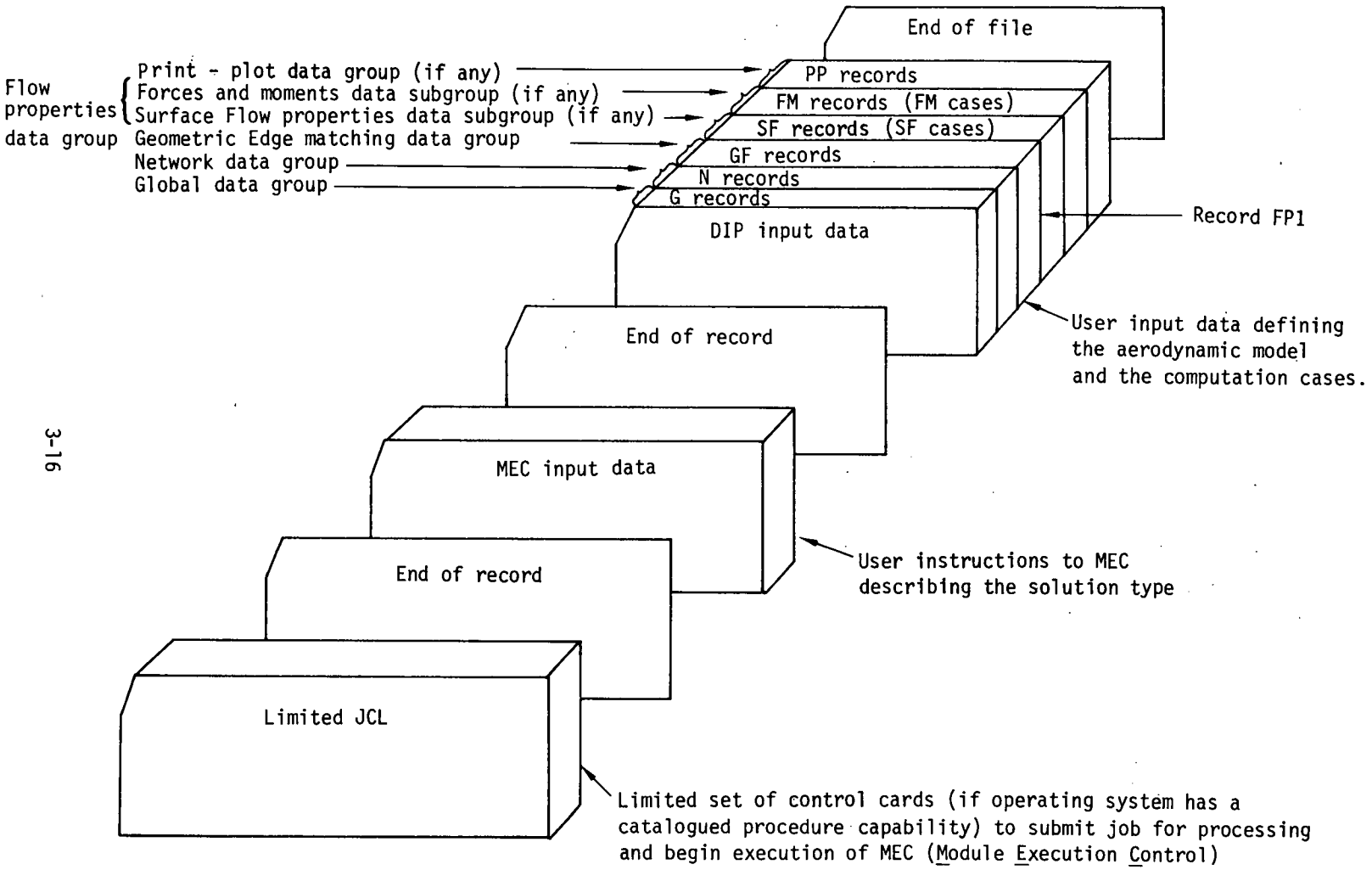
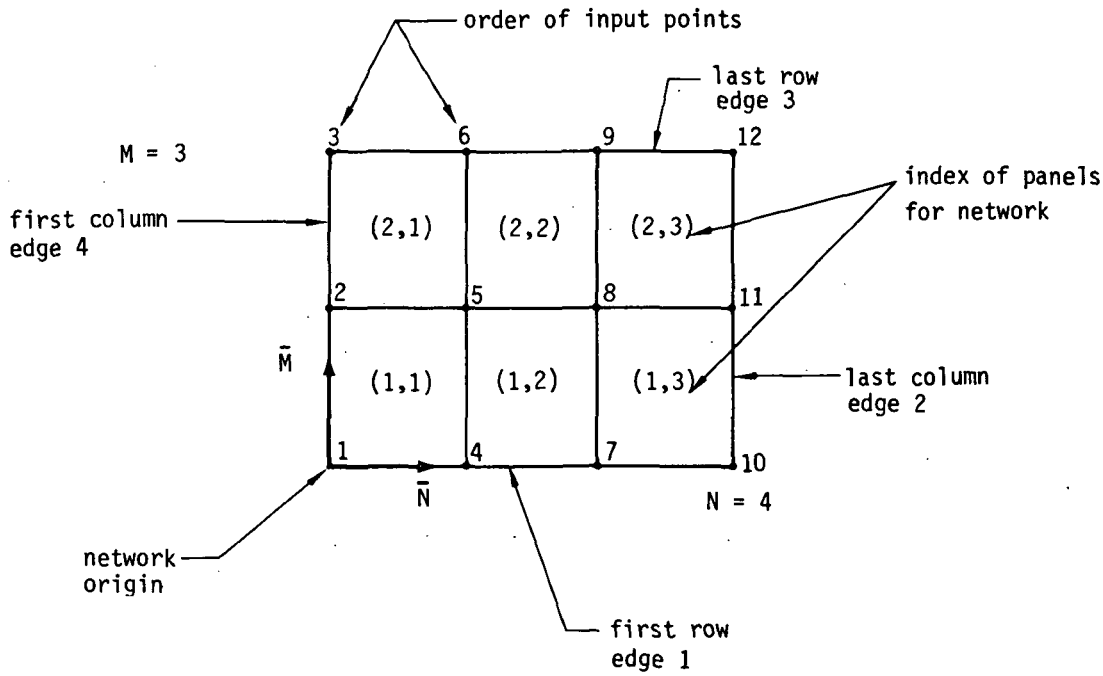



Figure 3.1 Deck to submit PAN AIR run




Note: The viewer is looking at the upper surface since $\bar{N} \times \bar{M}$ points toward the viewer.

Figure 3.2 Illustration of input ordering of panel corner points, indexing of network edges, and indexing of panels.

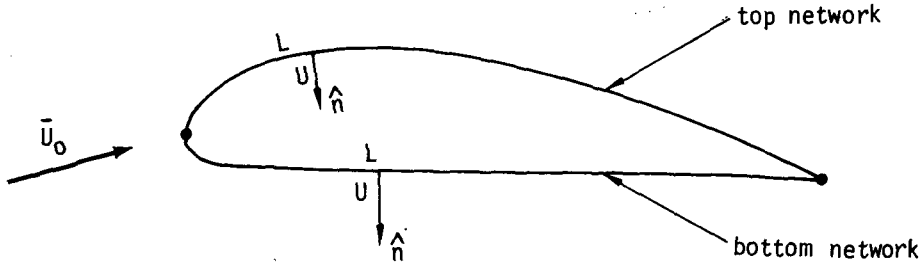



Figure 3.3 Example of thick configuration with an upper surface (bottom network) and a lower surface (top network) wetted by the physical flow field.

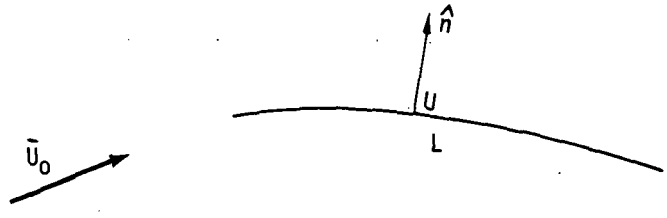
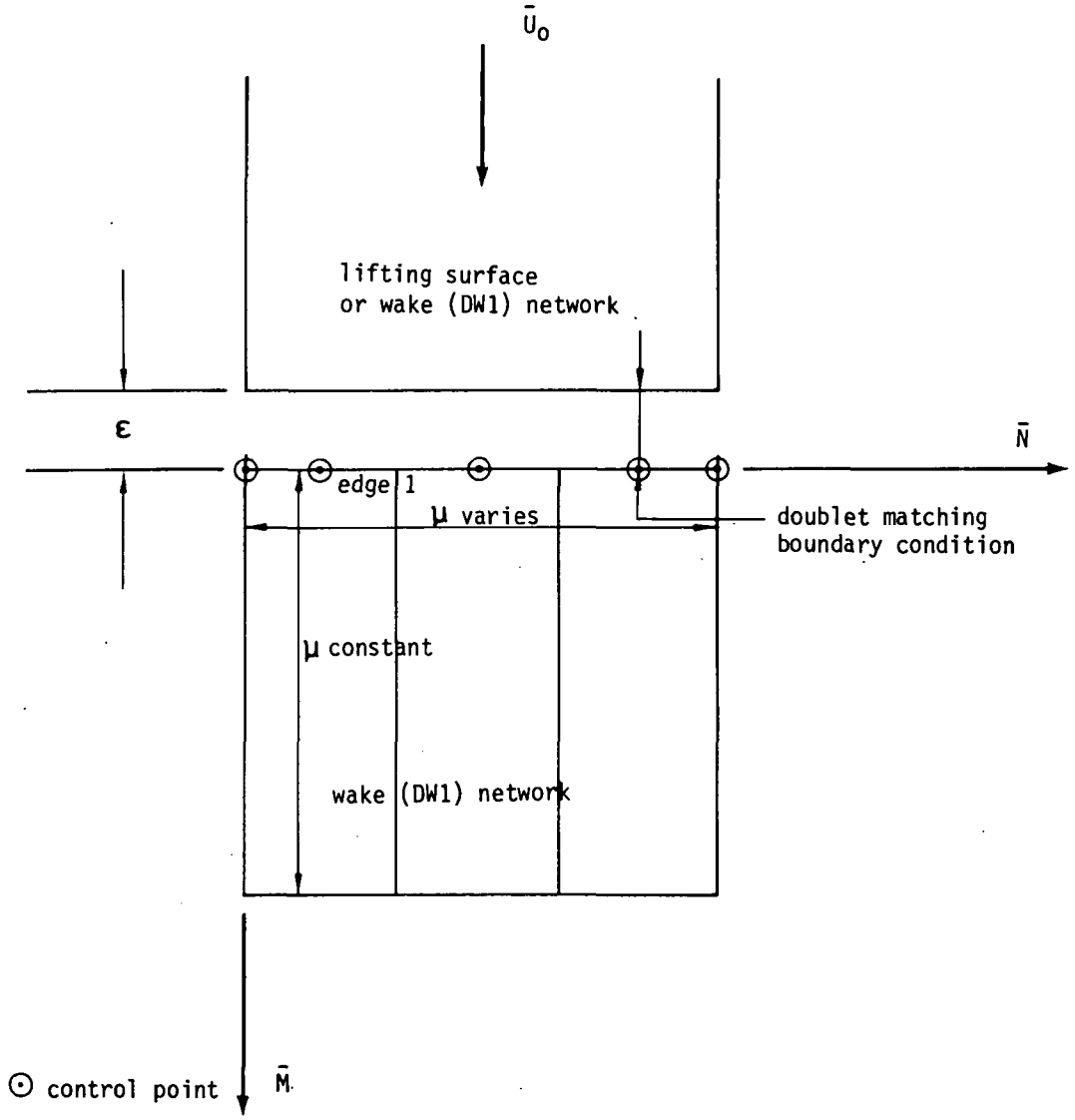



Figure 3.4 Example of thin (average) configuration




Note: The network edge abutments are defined by the program if the separation distance ε between the network edges is less than the geometric tolerance distance specified in record G7.

Figure 3.5 Example of use of DW1 wake network and class 1, subclass 4 boundary conditions

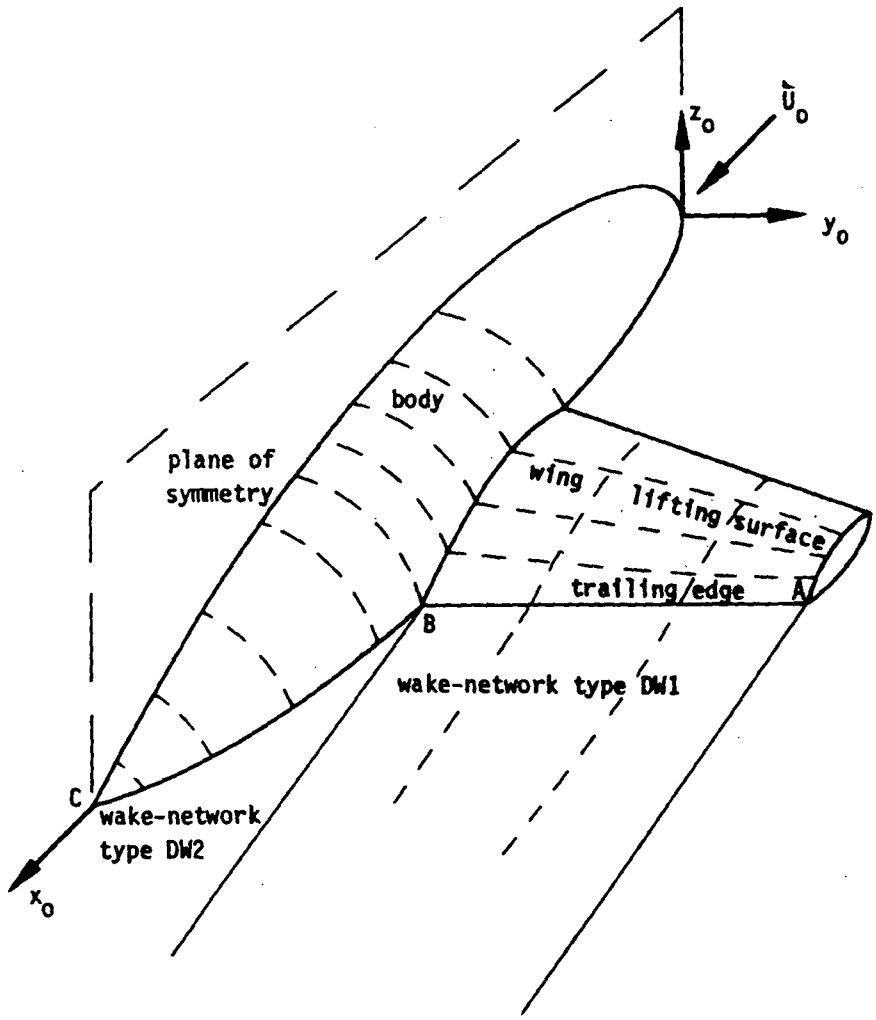



Figure 3.6 - Example of use of wake networks

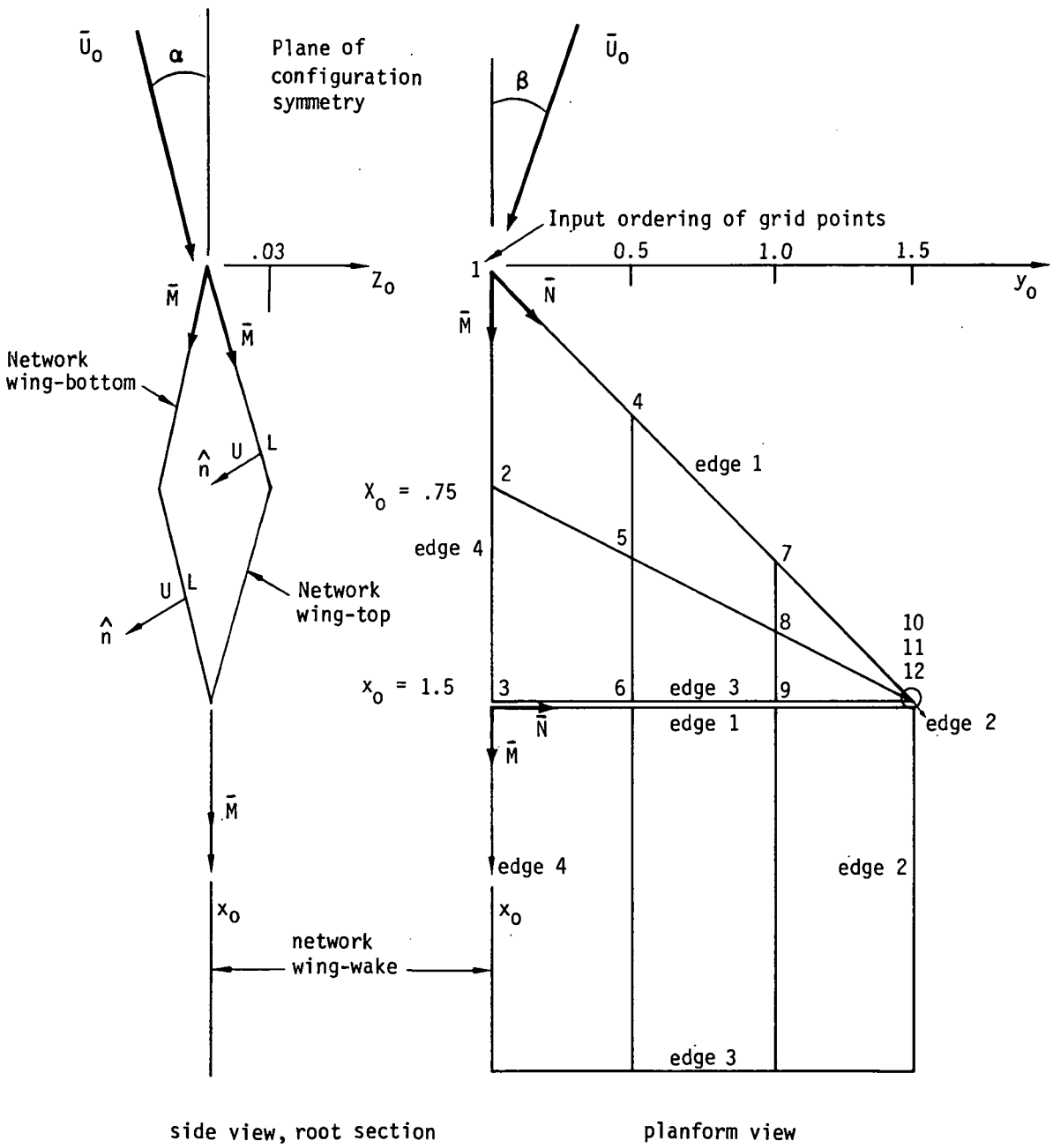



Figure 3.7 Delta wing configuration example of a standard aerodynamic analysis problem.

```
JOBNAME,T20,CM130000.                                          } CONTROL CARDS
USER,USRNAME,PASSWRD.                                          } AND JCL
ATTACH,PANPRC/UN=VSNAME.                                       }
CALL,PANPRC,RUN(NAME=VSNAME)                                   }
 - END OF RECORD -
PAN AIR                                                        }
SYSTEM VSNAME BOEING                                           }
RID=  VALIDATION CASE ABC - CLASS 1 BOUNDARY CONDITIONS        }
DATA BASE DIRECTIVE BLOCK                                      }
  APPEND ABC ALL                                               } MEC DATA
  UN = USRNAME ALL                                             }
  MUN = VSNAME ALL                                             }
END DATA BASE DIRECTIVE BLOCK                                  }
CHECK DATA RUN                                                 }
END PANAIR                                                     }
 - END OF RECORD -                                             }
```

where VSNAME is the account number under which all PANAIR program modules and database master definitions exist on disk and USRNAME is the account number of the user running a PANAIR problem.

Figure 3.8 - Listing of control cards, JCL and MEC data for example problem

```
*/ GLOBAL DATA GROUP <---------- COMMENT CARD
BEGIN GLOBAL DATA                          /G1
PID=THICK DELTA WING WITH CLASS 1 BOUNDARY CONDITIONS
UID=USER IDENTIFICATION
CONFIGURATION=FIRST-PLANE,0. 1. 0.,0. 0. 0.,ASYMMETRIC-FLOW  /G4
MACH=2.0  CALPHA=0.  CBETA=0.              /G5
ALPHA    BETA     UINF     SID             /G6
1.0      0.0      1.0      1-DEGREE-ALPHA  /G6.1
0.0      1.0      1.0      1-DEGREE-BETA   /G6.2
TOLERANCE FOR GEOMETRIC EDGE MATCHING=.001   /G7
*/ NETWORK DATA GROUP
BEGIN NETWORK DATA              /N1 <------ INSTRUCTION RECORD
NETWORK=WING-TOP, 3, 4, NEW     /N2A <----- INSTRUCTION-PARAMETER RECORD
 0.00 0.00 0.00, 0.75 0.00 +0.03, 1.50 0.00 0.00,
 0.50 0.50 0.00, 1.00 0.50 +0.02, 1.50 0.50 0.00,        } DATA RECORDS
 1.00 1.00 0.00, 1.25 1.00 +0.01, 1.50 1.00 0.00,        } (COMMAS ARE
 1.50 1.50 0.00, 1.50 1.50 +0.00, 1.50 1.50 0.00  /N2B   } OPTIONAL)
BOUNDARY CONDITION=1, LOWER                /N9
NETWORK=WING-BOTTOM, 3, 4, NEW             /N2A
 0.00 0.00 0.00, 0.75 0.00 -0.03, 1.50 0.00 0.00,
 0.50 0.50 0.00, 1.00 0.50 -0.02, 1.50 0.50 0.00,
 1.00 1.00 0.00, 1.25 1.00 -0.01, 1.50 1.00 0.00,
 1.50 1.50 0.00, 1.50 1.50 -0.00, 1.50 1.50 0.00  /N2B
BOUNDARY CONDITION=1, UPPER                /N9
NETWORK=WING-WAKE, 2, 4, NEW               /N2A
 1.5 0.0 .0, 10. 0.0 .0, 1.5 0.5 .0, 10. 0.5 .0,
 1.5 1.0 .0, 10. 1.0 .0, 1.5 1.5 .0, 10. 1.5 .0  /N2B
BOUNDARY CONDITION=1, WAKE 1               /N9
*/ GEOMETRIC EDGE MATCHING DATA GROUP - OMITTED
*/ FLOW PROPERTIES DATA GROUP
BEGIN FLOW PROPERTIES DATA                 /FP1
SURFACE FLOW PROPERTIES=SF-CASE-A          /SF1
NETWORKS-IMAGES=WING-TOP, INPUT, 1ST +  <---- RECORD CONTINUATION
            =WING-BOTTOM, INPUT, 1ST       /SF2    ONTO A SECOND CARD
SOLUTIONS=1-DEGREE-ALPHA, 1-DEGREE-BETA /SF3-DEFAULT
POINTS=ALL-CONTROL-POINTS                  /SF4A
SURFACE SELECTION=UPPER, LOWER             /SF5
SELECTION OF VELOCITY COMP=BOUNDARY-CONDITION   /SF6-DEFAULT
COMP OPTION FOR PRESSURES=UNIFORM-ONSET-FLOW    /SF7-DEFAULT
PRINTOUT=ALL                               /SF10A
VELOCITY CORRECTIONS=NONE                  /SF10B-DEFAULT
PRESSURE COEFFICIENT RULES=ISENTROPIC,LINEAR /SF10C
FORCES AND MOMENTS                         /FM1
AXIS SYSTEMS=RCS, 0. 0. 0., WAS, 0. 0. 0.  /FM3-DEFAULT
SOLUTIONS=1-DEGREE-ALPHA, 1-DEGREE-BETA /FM4-DEFAULT
PRINTOUT=COLSUM, RCS, NETWORK, CONFIGURATION  /FM5-DEFAULT
CASE=FM-CASE-A                             /FM7
NETWORKS-IMAGES=WING-TOP, INPUT, 1ST, REVERSE  +
            =WING-BOTTOM, INPUT, 1ST       /FM8
SURFACE SELECTION=UPPER                    /FM12-DEFAULT
SELECTION OF VELOCITY COMP=BOUNDARY-CONDITION  /FM13-DEFAULT
COMP OPTION FOR PRESSURES=UNIFORM-ONSET-FLOW   /FM14-DEFAULT
VELOCITY CORRECTIONS=NONE                  /FM15-DEFAULT
PRESSURE COEFFICIENT RULES=ISENTROPIC,LINEAR /FM16
END PROBLEM DEFINITION
```

Figure 3.9 - Listing of DIP input data for example problem

```
SYSTEM : PANAIR                    MODULE :  POINT DATA PROCESSOR  -  VERSION 1.0                    DATE  04/21/80
                RID =  VALIDATION CASE ABC - EXAMPLE WITH CLASS 1 BOUNDARY CONDITIONS /                    PAGE    1
                PID     THICK DELTA WING WITH CLASS 1 BOUNDARY CONDITIONS
                UID     USER IDENTIFICATION
 ------------------------------------------ GLOBAL DATA FOR THIS RUN ------------------------------------------

                                  NUMBER OF NETWORKS IN THE CONFIGURATION   3
                                                  NUMBER OF SOLUTIONS   2
                                             NUMBER OF PLANES OF SYMMETRY   1
                                                                           PLANE 1 WITH ASYMMETRIC FLOW
                                                FREESTREAM MACH NUMBER   2.000
                                                CALPHA = 0.000 CBETA = 0.000
                                              NUMBER OF USER OPTION CASES   1
```

a) Global options and data specified by user

Figure 3.10 - Surface flow properties (PDP module) printed output for example problem

```
        SURFACE FLOW PROPERTIES - CASE NUMBER   1  ID - SF-CASE-A                PAGE    2

NUMBER OF NETWORKS SELECTED     2

NUMBER OF SOLUTIONS SELECTED    2
                                SOLUTION  ALPHA  BETA  UNIF  SOLUTION ID
                                     1    1.000  0.000   1.0  1-DEGREE-ALPHA

                                     2    0.000  1.000   1.0  1-DEGREE-BETA

POINT TYPES SELECTED            PANEL  CENTER CONTROL POINTS
                                NETWORK EDGE  CONTROL POINTS
                                ADDITIONAL    CONTROL POINTS

SURFACES SELECTED    UPPER      LOWER

VELOCITY COMPUTATION OPTION(S)  B.C.

VELOCITY CORRECTION OPTION(S),  NONE      SA1       SA2
                                  1         0         0

PRESSURE COMPUTATION OPTION(S)  UNIFVL

********************************************** FLOW QUANTITIES SELECTED **********************************************

   ROW       COL     X-CORD    Y-CORD    Z-CORD      PWX       PWY       PWZ        WX        WY        WZ      WMAG
     1         1          1         1         1        1         1         1         1         1         1         1

    WN       PVX       PVY       PVZ        VX       VY        VZ      VMAG       PHI      PHIT    MLISEN    MLLINE
     1         1         1         1         1        1         1         1         1         1         1         1

MLSECO    MLREDU    MLSLEN    CPISEN    CPLINE    CPSECO    CPREDU    CPSLEN      GMUX      GMUY      GMUZ       PSI
     1         1         1         1         1         0         0         0         1         1         1         1

 SINGS     SINGD    SPDMAX    SPDCRT     CPVAC
     1         1         1         1         1

                1 = PRINT ONLY, 2 = DATA BASE STORAGE ONLY, 3 = BOTH, 0 = NONE
```

b) Calculations options specified by user

Figure 3.10 - continued

SURFACE FLOW PROPERTIES AT PANEL CENTER CONTROL POINTS CASE NUMBER 1 ID SF-CASE-A PAGE 3

SOLUTION NO : 1,ID : 1-DEGREE-ALPHA NETWORK NO : 1,ID : WING-TOP ,IMAGE : INPUT ORIENTATION : RETAIN

ALPHA = 1.00 BETA = 0.00 MACH = 2.000 CALPHA = 0.00 CBETA = 0.00

PRESSURE COMPUTATION UNIFVL VELOCITY COMPUTATION B.C. VELOCITY CORRECTION NONE

| ROW | COL | X-CORD | Y-CORD | Z-CORD | PWX<br>PVX<br>PHIT<br>GMUX<br>CPVAC | PWY<br>PVY<br>MLISEN<br>GMUY | PWZ<br>PVZ<br>MLLINE<br>GMUZ | WX<br>VX<br>MLSECO<br>PSI | WY<br>VY<br>MLREDU<br>SINGS | WZ<br>VZ<br>MLSLEN<br>SINGD | WMAG<br>VMAG<br>CPISEN<br>SPDMAX | WN<br>PHI<br>CPLINE<br>SPDCRT | SURFC |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 2 | 2 | .56263 | .24975 | .01252 | 0.00000<br>0.00000<br>.56276<br>.01349<br>-.35714 | 0.00000<br>0.00000<br>2.00000<br>-.00827 | 0.00000<br>0.00000<br>2.00000<br>-.00129 | .99985<br>.99985<br>2.00000<br>0.00000 | 0.00000<br>0.00000<br>2.00000<br>.02245 | .01745<br>.01745<br>2.00000<br>.00893 | 1.00000<br>1.00000<br>0.00000<br>1.50000 | .02251<br>0.00000<br>0.00000<br>.61237 | UPPER |
| | | | | | .04318<br>-.01439<br>.55383<br>.01349<br>-.35714 | .00918<br>.00918<br>1.95169<br>-.00827 | .02385<br>.02385<br>1.96414<br>-.00129 | 1.04303<br>.98545<br>1.95169<br>0.00000 | .00918<br>.00918<br>2.00000<br>.02245 | .04130<br>.04130<br>2.00000<br>.00893 | 1.04389<br>.98636<br>.02783<br>1.50000 | .00005<br>-.00893<br>.02795<br>.61237 | LOWER |
| 4 | 2 | 1.18775 | .24975 | .01249 | 0.00000<br>0.00000<br>1.18779<br>-.03754<br>-.35714 | 0.00000<br>0.00000<br>2.00000<br>.01461 | 0.00000<br>0.00000<br>2.00000<br>-.00450 | .99985<br>.99985<br>2.00000<br>0.00000 | 0.00000<br>0.00000<br>2.00000<br>-.05747 | .01745<br>.01745<br>2.00000<br>-.00067 | 1.00000<br>1.00000<br>0.00000<br>1.50000 | -.05740<br>0.00000<br>0.00000<br>.61237 | UPPER |
| | | | | | -.10568<br>.03523<br>1.18846<br>-.03754<br>-.35714 | -.01461<br>-.01461<br>2.13476<br>.01461 | -.05329<br>-.05329<br>2.09221<br>-.00450 | .89416<br>1.03508<br>2.13476<br>0.00000 | -.01461<br>-.01461<br>2.00000<br>-.05747 | -.03584<br>-.03584<br>2.00000<br>-.00067 | .89500<br>1.03580<br>-.06772<br>1.50000 | .00007<br>.00067<br>-.06859<br>.61237 | LOWER |
| 2 | 4 | .93750 | .74975 | .00751 | 0.00000<br>0.00000<br>.93749<br>.01819<br>-.35714 | 0.00000<br>0.00000<br>2.00000<br>-.02153 | 0.00000<br>0.00000<br>2.00000<br>-.00132 | .99985<br>.99985<br>2.00000<br>0.00000 | 0.00000<br>0.00000<br>2.00000<br>.02241 | .01745<br>.01745<br>2.00000<br>.00577 | 1.00000<br>1.00000<br>0.00000<br>1.50000 | .02251<br>0.00000<br>0.00000<br>.61237 | UPPER |
| | | | | | .05728<br>-.01909<br>.93171<br>.01819<br>-.35714 | .02243<br>.02243<br>1.93614<br>-.02153 | .02384<br>.02384<br>1.95228<br>-.00132 | 1.05713<br>.98075<br>1.93614<br>0.00000 | .02243<br>.02243<br>2.00000<br>.02241 | .04130<br>.04130<br>2.00000<br>.00577 | 1.05817<br>.98188<br>.03722<br>1.50000 | .00009<br>-.00577<br>.03735<br>.61237 | LOWER |
| 4 | 4 | 1.31263 | .74975 | .00750 | 0.00000<br>0.00000<br>1.31256<br>-.03426<br>-.35714 | 0.00000<br>0.00000<br>2.00000<br>.01260 | 0.00000<br>0.00000<br>2.00000<br>-.00411 | .99985<br>.99985<br>2.00000<br>0.00000 | 0.00000<br>0.00000<br>2.00000<br>-.05750 | .01745<br>.01745<br>2.00000<br>.00316 | 1.00000<br>1.00000<br>0.00000<br>1.50000 | -.05740<br>0.00000<br>0.00000<br>.61237 | UPPER |



c) Calculated flow quantities

Figure 3.10 - concluded

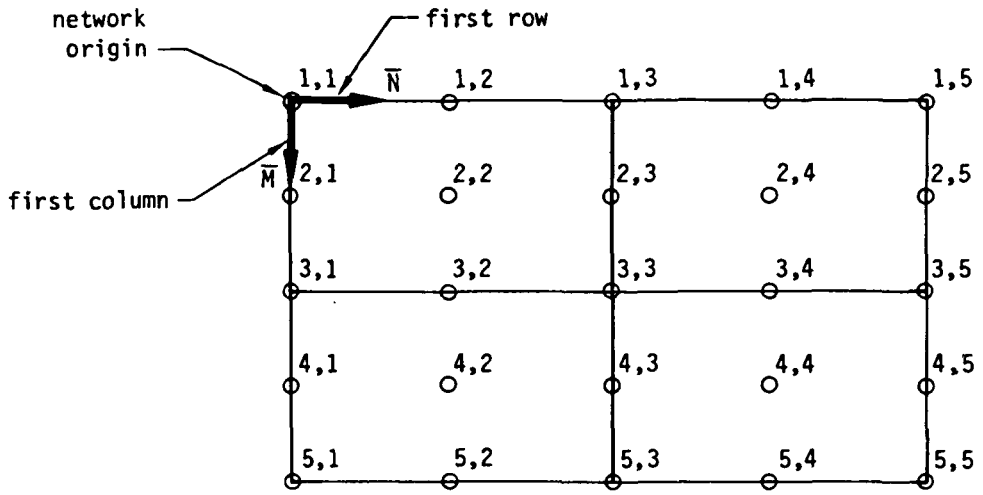



Figure 3.11 - Illustration of indexing of "enriched" grid point array

```
**********************************************************
**********************************************************
*****                                                *****
*****     CONFIGURATION DATA PROCESSOR               *****
**********************************************************
*****     CASE NUMBER   =   1  FM-CASE-A             *****
*****                                                *****
**********************************************************
**********************************************************
 OPTIONS SELECTED ARE
 --------------------

*****                                                *****
NUMBER OF NETWORKS           =   2
NUMBER OF SOLUTIONS          =   2
PRESSURE RULES               = ISENTROPIC LINEAR
VELOCITY COMPUTATION METHODS =B.C.
VELOCITY CORRECTION          =NONE
SURFACE TYPE                 =UPPER
PRESSURE COMPUTATION OPTION  =UNIFORM ONSET FLOW


 PROGRAM OUTPUTS
 1=PRINT  2=DATABASE  3=BOTH  0=NONE

COLUMN SUM IN RCS   3
COLUMN SUM IN WAS   0
COLUMN SUM IN BAS   0
COLUMN SUM IN SAS   0
PANEL SUM IN RCS    0
PANEL SUM IN WAS    0
PANEL SUM IN BAS    0
PANEL SUM IN SAS    0
NETWORK SUM         3
CONFIGURATION SUM   3

ACCUM. OPTIONS
     VEL. COMPUTAT. N/A
     VEL. CORRECTN. N/A
     PRESSURE RULE  N/A



SIZE OF CDP TEMPORARY DATABASE   =    2592
```

a) Case options specified by user

Figure 3.12 - Forces and moments (CDP module) printed output for example problem

```
RID =  VALIDATION CASE ABC - EXAMPLE WITH CLASS 1 BOUNDARY CONDITIONS /
PID     THICK DELTA WING WITH CLASS 1 BOUNDARY CONDITIONS
UID     USER IDENTIFICATION

                    NUMBER OF NETWORKS IN THE CONFIGURATION   2
                    NUMBER OF SOLUTIONS                       2
                    NUMBER OF PLANES OF SYMMETRY              1
                          PLANE 1 WITH ASYMMETRIC FLOW
                    FREESTREAM MACH NUMBER  2.000
                          CALPHA =   0.000  CBETA =   0.000 (DEGREES)
```



b) Global options and data specified by user

Figure 3.12 - continued

```
                NUMBER OF NETWORKS SELECTED   2

                     SURFACE SELECTED        UPPER

                VELOCITY COMPUTATION OPTIONS B.C.

                VELOCITY CORRECTION  OPTIONS NONE

                PRESSURE RULES SELECTED ISEN    LINE

AXIS        COORD. OF MOMENT REFERENCE     EULER ANGLES
RCS       0.00000   0.00000   0.00000
WAS       0.00000   0.00000   0.00000

        GLOBAL REFERENCE                          AREA   CORD  SPAN
                                                  1.000  1.000  1.000

        LOCAL REFERENCE                           AREA   CORD
                                                  1.000  1.000

             NUMBER OF SOLUTIONS SELECTED   2
             SOLUTION NO.  ID
                     1 1-DEGREE-ALPHA
                     2 1-DEGREE-BETA
```



c) Other options specified by user

Figure 3.12 - continued

CONFIGURATION FORCES AND MOMENTS CASE NUMBER 1 ID : FM-CASE-A PAGE 3

SOLUTION NO : 1,ID : 1-DEGREE-ALPHA NETWORK NO : 1,ID : WING-TOP REVERSE ,IMAGE : INPUT

PRESSURE COMPUTATION = UNIFORM ONSET FLOW VECTOR ALPHA = 1.00,BETA = 0.00,MACH = 2.000,CALPHA = 0.00,CBETA = 0.00

| | | VEL. OPT. | VEL. CORR | AXIS SYS. | PRS. RULE | AREA | VOLUME FLOW | FORCES FX | FY | FZ | MOMENTS MX | MY | MZ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| COLUMN | 1 SUM | B.C. | NONE | RCS | ISEN | .62575 | .01091 | .00134 | -.00032 | .01783 | .00400 | -.02498 | -.00052 |
| | | | | | LINE | | | .00134 | -.00032 | .01721 | .00389 | -.02436 | -.00053 |
| COLUMN | 2 SUM | | | | ISEN | .37545 | .00654 | .00089 | -.00026 | .00909 | .00623 | -.01377 | -.00089 |
| | | | | | LINE | | | .00087 | -.00027 | .00792 | .00533 | -.01235 | -.00089 |
| COLUMN | 3 SUM | | | | ISEN | .12515 | .00218 | .00023 | -.00012 | -.00017 | -.00034 | .00004 | -.00042 |
| | | | | | LINE | | | .00017 | -.00011 | -.00122 | -.00155 | .00158 | -.00034 |
| NETWORK | 1 SUM | | | | ISEN | 1.12635 | .01963 | .00246 | -.00069 | .02674 | .00989 | -.03871 | -.00184 |
| | | | | | LINE | | | .00237 | -.00071 | .02390 | .00766 | -.03513 | -.00176 |
| | | | | WAS | ISEN | | | .00292 | -.00069 | .02670 | .00986 | -.03871 | -.00201 |
| | | | | | LINE | | | .00279 | -.00071 | .02386 | .00763 | -.03513 | -.00189 |



d) Calculated force and moment coefficients

Figure 3.12 - concluded

# 4.0 System Architecture

## 4.1 Software Overview

PAN AIR is a modular software system. The modules of the system are "standalone" programs, each with its own well defined function.

Execution of the individual programs is controlled by an executive module, MEC, which interprets user directives and generates control cards to execute the programs in the proper sequence (see sections 5.1 and 6).

The individual programs are connected only by the data passing between them. SDMS, a Scientific Data Management System (see PAN AIR Maintenance Document, Section 13), is used to define the format of the data and handle the transfer of information between the programs and disk.

The PAN AIR modules are listed below.

| | |
|---|---|
| MEC | Module Execution Control |
| DIP | Data Input Processor |
| DQG | Defining Quantities Generator |
| MAG | Matrix Generator |
| RMS | Real Matrix Solver |
| RHS | Right Hand Side |
| MDG | Minimal Data Generator |
| PDP | Point Data Processor |
| CDP | Configuration Data Processor |
| PPP | Print/Plot Processor |

The MEC module is discussed in section 4.4 The purpose, data requirements and processing steps of each other PAN AIR module are described in section 4.2. Figure 4.1 displays the relationship of PAN AIR with the data bases and shows the normal external communication. Figure 4.2 shows the standard execution sequence(s) for the programs.

Except for the PPP and MAG modules, each module produces a single permanent data base having a default name which is the name of the module creating it. The data base created by the MAG module is named MAK. Module PPP does not produce any database files. Instead it produces several output files for use in plotting and/or printing selected data.

Section 4.3.2 describes the flow of data base information between PAN AIR programs for different solution options. Section 8.3 discusses the format and content of the data bases.

## 4.2 Technical Modules of PAN AIR

The following sections describe the individual PAN AIR modules in terms of:

1. Purpose
2. Tasks performed (and major options)
3. Input data
4. Output data

More detail is given on input and output data in section 7 and 8. The executive module MEC is described in sections 4.4 and 6 of this manual. In addition, the design of each program is described in a separate document, the PAN AIR Maintenance Document.

### 4.2.1 DIP - DATA Input Processor

#### 4.2.1.1 Purpose

The DIP module reads user input data which describes the PAN AIR problem and stores the data on the DIP data base.

#### 4.2.1.2 Tasks Performed

Following the execution of the MEC module, the DIP module accesses the MEC data base to read the type of PAN AIR problem to be run. From this dataset, DIP can determine whether a new or updated data base is to be created from the inputs. The possible options, described in detail in section 4.3.2, are as follows:

1. Creation run - no preexisting data base.

2. Post processing run - use existing data base and add PDP, CDP and PPP directives to it.

3. Right-hand-side update run - use existing data base and update only "solution data."

4. IC update run - use existing data base and update geometric data.

The input data are read in free field format from card images. Each card image is read, printed and processed. The data are organized and stored on the DIP data base. The initial input data for DIP should contain global data to describe the boundary value problem and global defaults, network data to describe the surface definition and boundary conditions, and the geometric edge matching data to describe network edge matching. The above data (original or updated) is required for solving a potential flow solution.

The post processing input data for DIP may contain post-solution calculation cases and data base output directives. Both of these types of data require a preexisting DIP data base plus the results of a potential flow solution on the data base produced by the MDG module.

#### 4.2.1.3 Input Data

The DIP module reads data in card form or from a card image file created by the user, and also reads from the MEC database created during the execution of the MEC module. See section 7 for detailed information on the user-defined DIP input data (e.g., input options, syntax, etc.).

#### 4.2.1.4 Output Data

The output data consists of printouts and a DIP data base. The printed data consists of the input data and error diagnostic information. For details of the data, the reader is referred to section 8.1.2.

### 4.2.2 DQG - Defining Quantities Generator

#### 4.2.2.1 Purpose

The Defining Quantities Generator computes and defines a large number of intermediate quantities required for solution of the potential flow problem. These quantities fall into three classes: control data, geometrical data and boundary condition data.

The control data consists of indices of all singularity parameters and control points in the configuration as well as an indication of those singularity parameters that are "known" and those singularity parameters and control points that are "null," (not used to solve the problem).

The geometrical data includes descriptions of network abutments and abutment intersections, the coefficients of the source and doublet splines that define the singularity strengths over the surfaces of the networks and those geometrical properties of panels which are required to compute the AIC matrix in module MAG.

The boundary condition data processing includes assignment of user specified boundary conditions as well as automatic imposition of doublet matching conditions at network boundaries.

All of the data are stored on the DQG data base. A small amount of printed data is available to the user through the selection of certain print options in the input to DIP.

DQG also analyzes the configuration for many types of errors which may lead to an erroneous or singular solution and produces diagnostic information that the user might use to correct his input to DIP.

#### 4.2.2.2 Tasks Performed

The basic tasks of DQG are performed in the six primary overlays of DQG. (A seventh primary overlay performs some useful but perfunctory communication to the user.) In the first overlay, data from the DIP data base are read, copied and (in some cases) transcribed onto the DQG data base. In the second overlay, the data associated with individual networks are defined. Also included are error checks on network size and indexing of singularity parameters and control points. The third overlay of DQG deals with the inter-relationship of networks with each other: abutments and abutment intersections. User defined abutments are imposed and a search is made for any additional abutments in the configuration. A determination is made of network edges and corner points where doublet matching boundary conditions will be imposed. If additional paneling is required to fill in gaps between network edges, gap filling panels are generated. Also network overlaps are found, if any, and diagnostics are given as printed output. The fourth overlay assigns the appropriate number and type of boundary conditions at each control point in the configuration. The fifth overlay constructs the source and doublet splines over the network surfaces. The sixth overlay computes panel geometrical data, assembles matrices describing source and doublet strength over the surface of the panel and computes the moments of source and doublet strength over the surface of the panel. The seventh overlay produces printed output of control point data and boundary condition data.

#### 4.2.2.3 Input Data

All input data to DQG comes from the DIP data base. The input data consists of global properties of the problem (Mach number, compressibility vector, number of networks), network data (size of network, singularity and edge types), geometrical data (panel corner point coordinates, user described abutment data) and boundary conditions that the user wishes to impose at control points.

#### 4.2.2.4 Output Data

The major output produced by DQG is a data base. Some of the data base information is accessible to the user through the execution of module PPP but for the most part the information stored on the data base is not essential to the user. If access to this data is desired, the user must write his own FORTRAN program to call the appropriate SDMS routines which will transfer the data from the disk. An example of such a program is shown in section 1-A of the PAN AIR Maintenance Manual. See also section 13 of the PAN AIR Maintenance Document.

DQG analyzes the user's configuration for many kinds of errors which might affect the accuracy of the solution. Diagnostic information provided to the user consists of fatal error messages and warning messages. When a fatal error occurs in a DQG overlay, that overlay will complete its operations (as much as possible) but subsequent overlays will not be executed. However if during the execution of an overlay more than ten fatal errors accumulate, no more processing in that overlay will occur, and the program will terminate execution.

In addition there are several user-selectable options for printed output. These include warning messages, network corner point coordinates, network enriched grid point coordinates, empty space abutment descriptions, descriptions of all abutments, control point data, boundary condition data and a predictive estimate of resources required to obtain a full solution to the problem.* After each overlay the computer resources used for the execution of DQG since initial execution is printed.

### 4.2.3 MAG - Matrix Generator

#### 4.2.3.1 Purpose

The Matrix Generator module uses output from the DQG data base to generate influence coefficients, incorporate symmetry constraints, assemble the influence coefficient (IC) matrix, and perform operations related to the transformation of the boundary value problem into systems of simultaneous linear equations.

#### 4.2.3.2 Tasks Performed

The singularity and control point data from DQG are grouped into the catagories of updatable and non-updatable. In addition, the singularity data are further divided into known and unknown partitions. The new grouping of data is put into two directories relating DQG data and MAG data. The directories are stored in the MAK database. A number of matrices are formed from the DQG data. First, the panel geometry specifications and the reformatted control point data are obtained from the DQG and MAK data bases respectively. The panel influence coefficients (PIC) are then formed from complex computations defined in section 4.2.2 of the PAN AIR Theory Document. These PIC matrices are symmetrized to form the entries to the IC matrices. These IC matrices are stored by column on a temporary data base. Next, the IC matrices in required row form (up to 5000 words long) are formed from the column form in which they were stored on the temporary data bases. The aerodynamic influence coefficients (AIC) are then constructed from the boundary conditions specified by DQG and the IC matrices. The AIC matrices which correspond to the known and unknown singularities are stored in the MAK data base. Finally, the influence coefficients IC's needed by the MDG module are transferred from the temporary data base to the MAK data base.

#### 4.2.3.3 Input Data

All input data comes from the DQG data base. It consists of global data (flow condition), network specifications, control point specifications, boundary condition specifications, singularity specifications and panel specification data.

*The predictive estimate is not available in Version 1.0

#### 4.2.3.4 Output Data

Very little printed output is provided by MAG. The output consists of execution error diagnostic information. Also, for a successful run, a summary of IC (Influence Coefficient) and AIC (Aerodynamic Influence Coefficient) matrices generated by MAG is printed.

### 4.2.4 RMS - Real Matrix Solver

#### 4.2.4.1 Purpose

The Real Matrix Solver (RMS) module decomposes the partition of the AIC matrix associated with unknown singularity parameters.

#### 4.2.4.2 Tasks Performed

The RMS matrix solution subroutines operate on the matrices in "blocked partitioned format." The major tasks of RMS are to block and decompose the AIC matrices into upper and lower triangular matrices and pivot terms for use in the solution process in the RHS module.

#### 4.2.4.3 Input Data

The input data for RMS consist of the updatable and/or non-updatable AIC matrices corresponding to the unknown lambda's (singularity parameters as shown in the equation in section 2.3.2) from the MAK data base.

#### 4.2.4.4 Output Data

The output data are stored on the RMS data base and consist of the decomposed AIC matrices and blocking information. The RHS module uses this data to obtain a solution. If a fatal execution error occurs, printed diagnostic information is given before the run aborts.

### 4.2.5 RHS Right-Hand-Side Generator

#### 4.2.5.1 Purpose

The RHS module creates the right-hand-side equality constraints for the linear system of equations defining the aerodynamic problem. The constraints are formed from the boundary conditions and other known quantities. The module also obtains the solutions to the linear system for each control point by forward and backward substitution with the decomposed AIC matrix obtained from the RMS module.

The constraint data for the right-hand-side are obtained from the DIP data base and transformed into a usable form by RHS. The transformed constraint data are then stored in a temporary data base.

The RHS module also generates the symmetrized right-hand-side matrix consisting of two partitions; those for the known AIC elements and those for the unknown. Using matrix partition algebra and backward substitution on the decomposed AIC matrix, all singularity parameters for all solutions are found.

#### 4.2.5.3 Input Data

The constraint data is obtained from the DIP data base. The data consists of the network specification, network bulk data, closure conditions, general boundary condition coefficients and specified flow and local onset flow information. The directory of the control point and DQG conversion index information are obtained from the MAK data base. The boundary condition type data is obtained from the DQG data base. The blocked and decomposed AIC matrix is obtained from the RMS data base.

#### 4.2.5.4 Output Data

The RHS module generates a permanent data base. Printed messages consist of error diagnostics.

### 4.2.6 MDG - Minimal Data Generator

#### 4.2.6.1 Purpose

The Minimal Data Generator module is the primary interface of the upstream, PAN AIR modules, DIP, DQG, MAG and RHS, with the post processing PAN AIR Modules, PDP and CDP. It reads geometry, influence coefficient, and singularity data to generate a minimal data base of information at control point and panel grid point locations. This data, used by PDP and CDP, consists of geometric information and basic flow quantities: source and doublet singularities, average potential, average mass flux, and in specific instances, average velocity in three components. All basic flow quantities are stored on the MDG database for all solutions and (if planes of symmetry are present) for all distinct images. (See PAN AIR Theory Document, sections 5.7.2 and K.1)

The minimal data base generated by MDG enables PDP and CDP to process data without accessing the DQG, MAK, and RHS data bases and have that data available in a convenient format at either control points or panel grid points for a given image and solution.

4.2.6.2 Tasks Performed

MDG opens and checks the condition of the data bases from DQG, MAG, and RHS to assure that other upstream modules have executed without errors. It forms the MDG permanent data base for the global, network-spec, and solution data sets. For each network, the control points are determined for each panel. The control point and grid point geometry is output to the MDG data base.

The IC-matrices from MAK and the singularities from RHS are postmultiplied to form control point values of average potential, mass flux and velocity in three components if specified by the user. Singularities are reformatted uniformly and unsymmetrized.

Using spline vectors created by DQG, singularity values are obtained at nine defining grid points and five defining grid points for doublet and source singularities respectively on each panel (see figure 4.3). Subpanel splines are used to calculate singularity values at control points.

At control point locations where IC values were not calculated, values are calculated from the boundary conditions. If IC's were calculated, the mass flux is calculated from the inner product of these velocities and the control point conormal. The values of average potential, mass flux, velocity, if specified, and singularities at control points are placed on the MDG data base.

Potential splines, similiar to DQG doublet analysis splines, are calculated to produce values of flow quantities at grid points from values at control points. The same quantities output at control points are output at grid points on each network.

4.2.6.3 Input Data

MDG receives its data from the DQG, MAK and RHS data bases. From DQG it reads global data, network data, panel data, spline data, control point information and boundary condition data. From MAK it reads the IC matricies, and from RHS the singularities, solution data, right-hand-side values and symmetry data.

The DQG global dataset consists of information pertinent to the run such as the number and order of networks, number of right-hand-side solutions, Mach number, and number of planes of symmetry. Network data gives the network size and type of source and doublet singularities on the network. The spline data consist of source and doublet splines for calculating singularities at grid point locations from the singularity locations. Panel data contains the geometry quantities stored on the MDG geometry datasets, and the subpanel splines for splining to control points, plus coordinates and coordinate transformations. The control point data gives the control point index of each control point from its grid point location and its coordinates. The boundary condition data indicates which boundary conditions are imposed at each control point for potential, mass flux and velocity.

The MAK data base contains the influence coefficient (IC) matrices. These influence coefficients are multiplied by the singularities to give values at

control points of potential, mass flux, and possibly velocity, depending on the boundary conditions.

The RHS data base has singularities stored by columns (all singularities for a single solution) and by rows (a set of solutions for each singularity). The RHS values are used in evaluating the boundary condition equation for potential and mass flux. The RHS symmetry data determines the number of images and the RHS/MAG partitioning of singularities.

#### 4.2.6.4 Output Data

The output from MDG consists of a small amount of printed output and the MDG data base. The printed output consists mainly of error diagnostics if they occur or a message that a successful run has occured. The data base output data is described in section 8.2.7. It is diverse and consists of global, network, solution, control point geometry, grid point geometry, control point and grid point data.

### 4.2.7 PDP - Point Data Processor

#### 4.2.7.1 Purpose

The Point Data Processor module is designed to compute flow quantities on configuration body and wake surfaces. These surface flow quantities consist of perturbation and total potential, perturbation and total velocities, perturbation, total and normal mass flux, pressure coefficients and local Mach numbers for isentropic, linear, second-order, reduced second-order and slender body approximations.

Each of these computed data items is printed out and/or stored on a permanent data base for later retrieval as selected by the user. The PDP data base is generated only if data base storage is requested by the user.

The user options are available to PDP in the DIP data base and the configuration geometry and other minimal data is available in the MDG data base.

#### 4.2.7.2 Tasks Performed

The PDP module gets the processed user input from the DIP data base. These consist of computation options for potential, velocity, velocity correction and computation schemes, pressure coefficients and local Mach numbers. The user can specify several cases of options (a maximum of 100) for a full PDP run.

The user has the option of requesting a printed output of the computed quantities for each case. Since the generated data base can be very large, PDP scans the user options for all the cases and produces a printed report on estimated disk storage requirements (see section 8.1.8 of this document).

The configuration geometry and a minimal set of velocity data (perturbation velocities at points computed from the AIC matrices and the local onset flow velocities etc.) are available to PDP in the MDG data base. PDP computes the average and difference velocities at user selected point types for each selected network, image and solutions and uses these data to compute the perturbation and total velocities on each selected surface. The velocities are corrected by PDP by the user selected correction schemes and are then used to compute pressure coefficients and local Mach numbers for the selected rules (isentropic, linear, second-order, reduced second-order and slender body).

These flow quantities are written to the output file and/or to the PDP data base for later retrieval by the PPP module.

#### 4.2.7.3 Input Data

The processed user options data for surface and wake flow properties are provided by the DIP data base.

The minimal set of configuration geometry and velocity data is provided by the MDG data base. These consist of network geometry for control and grid points, average potential, average velocity and local onset flow velocities.

#### 4.2.7.4 Output Data

The Point Data Processor generates a permanent data base containing user selected flow quantities on the configuration body and wake surfaces. The module also produces as printed output the flow quantities selected for printing by the user. The printed output is designed for easy reference of data. The global data for the run and the selected options for each case are printed out. The run and problem identification, date of run, network, image, solution indices and the case numbers are available in the report headers on each page of the output. The selected flow quantities, potential, velocities, mass flux, pressure coefficients and local Mach numbers are printed out for each velocity correction, velocity computation and surface selected. This is repeated for each image, network and solution selected by the user.

An estimate of disk storage requirements for a full PDP run is produced at the beginning of each run. At the end of each run, an error and accounting summary report is printed.

### 4.2.8 CDP - Configuration Data Processor

#### 4.2.8.1 Purpose

The Configuration Data Processor is designed to compute forces and moments on configuration body and wake surfaces. The computed forces and moments are printed out and/or stored in a permanent data base for later retrieval as selected by the user. The CDP permanent data base is generated only if it is requested by the user.

The user options for CDP are obtained from the DIP data base and the configuration geometry and other minimal data are obtained from the MDG data base.

#### 4.2.8.2 Tasks Performed

The Configuration Data Processor obtains the processed user input from the DIP data base. These consist of lists of user selected networks, solutions, axis systems and configuration options for forces and moments. The user can specify several cases of options (a maximum of 100) for a full CDP run.

The user has the option of requesting printed output and/or storage in CDP data base of the computed force and moment data for each case of options. Since the generated data base can be very large, CDP scans the user options for all the cases and prints out the estimated data storage requirements for a full run.

The configuration geometry and a minimal set of velocity data are available from the MDG data base. The CDP module computes the average and difference velocities on the points of each panel, corrects these velocities according to the user selected correction schemes, and computes the selected pressure coefficients from the velocity in a user-selected preferred direction. These pressure coefficients are used to compute forces and moments on each panel. The edge forces and the corresponding moments are also computed on user selected network edges.

The computed forces and moments are transformed to user selected axis systems (a maximum of 4) and printed out and/or stored in the CDP data base for later retrieval by the user with the PPP module.

The CDP module allows the user to sum forces and moments for all panels in a column, for all columns in a network and for all networks in a configuration. A configuration consists of all selected networks for a particular case. In addition the user may request to sum or accumulate forces and moments for selected configurations of a PAN AIR run.

#### 4.2.8.3 Input Data

The processed user option data for computation of forces and moments are available from the DIP data base.

A minimal set of configuration geometry and velocity data is provided by the MDG data base. These consist of network geometry for control and grid points, average velocities and local onset flow velocities.

#### 4.2.8.4 Output Data

The Configuration Data Processor generates a permanent data base containing user selected forces and moments on the configuration body and wake surfaces. The module also produces as printed output the forces and moments data selected for printing by the user. The global data for the run and the

selected options for each case are also printed out. The run and problem identification, date of run, network, image and solution indices, case number and all identifying labels are provided in each page of the output report. The computed forces and moments are printed for each velocity correction, velocity computation, pressure rule, and axis system selected by the user, for each image, network and solution selected.

### 4.2.9 PPP - Print/Plot Processor

#### 4.2.9.1 Purpose

The Print Plot Processor module extracts user selected information from selected PAN AIR data bases and prepares the data in a format suitable for processing by plot programs external to PAN AIR.

#### 4.2.9.2 Tasks Performed

The PPP module extracts user selected data from the DQG, PDP, and CDP data bases and reformats the information for use in preparing plot files. The data are selected from a menu consisting of geometry data from DQG, point data from PDP, and configuration data from CDP.

#### 4.2.9.3 Input Data

User instructions selecting the data to be processed are read from the DIP data base. Based upon these instructions PPP reads and creates plot files from the following data bases:

| | |
|---|---|
| DIP | global data and options selected by user for PPP. |
| DQG | network geometry (panel corner points only) and global data. |
| PDP | pressures, velocities, mass flux, etc. at control points for each case for each solution, network, velocity computation option and velocity correction option selected by user. |
| CDP | forces and moments for panels, columns of panels, networks and configurations. |

#### 4.2.9.4 Output Data

PPP generates two output items:

- A printed listing describing the information extracted from the PAN AIR data base(s).
- A coded file containing the user requested data to be plotted.

## 4.3 System Interfaces

### 4.3.1 Modes of Input/Output

Figure 4.4 displays the types of data going in and out of the PAN AIR system. All data used within PAN AIR is originally read by the system from cards or a disk file containing card images. The output data is generated in the following forms:

- Printed output from each program
- Data file of plot information from PPP
- The SDMS data bases produced by each program
- The control cards produced by MEC

However, the control cards generated by MEC are executed immediately after being generated and then normally allowed to disappear. The control cards are described in section 8.4.

#### 4.3.1.1 Card Input Data

Users generate a card deck to run PAN AIR. The deck contains three sets of records (each separated by an "end-of-record" card) as shown in figure 4.5.

The first set of CDC control cards retrieves the MEC module, executes MEC and then executes the proper sequence of PAN AIR programs. This limited set of control cards is described in section 5.2.

The second set contains the user directives read by MEC. The directives define the type of problem to be solved and indicate where the data bases are to be found or stored. The MEC directives are described in section 6.

The third set is a detailed definition of the model and problem options. It contains network geometry and boundary conditions, flow options, solution options and other information to be read by DIP. Some data may be omitted and the program will assume defaults. Section 3 is a beginner's guide to the DIP input data and section 7 describes the DIP data in detail.

#### 4.3.1.2 Printed Output

Each PAN AIR module generates some printed output. The output is labelled to indicate the beginning and end of each module's processing. Section 8 describes the print options and how to request them.

#### 4.3.1.3 Plot Data File

According to user instructions (described in section 7.7) the PPP module will extract information from the PAN AIR data bases and generate a file of data in a format suitable for plotting. The file is described in section 8.3.

### 4.3.2 Description of PAN AIR Data Flow

#### 4.3.2.1 Check Data Run

PAN AIR has an option to check the input data before a problem is executed. The MEC and DIP modules are executed with the option of adding DQG and/or PPP to obtain a file for plotting the data. Figure 4.6 illustrates the flow. Example 1 of section 8.5 gives the input/output for a check data run followed by a full PAN AIR run. For this run, the check data run would execute but the full potential flow problem would not.

A combination of a check data run and other PAN AIR problems can be specified. In this case, control cards for both the check data run and the other PAN AIR problems are listed but only the check data run will be executed. This enables the user to check both the DIP input data and the control cards specified for the desired PAN AIR problem.

#### 4.3.2.2 Standard Potential Flow Problem

The standard potential flow problem executes the modules MEC, DIP, DQG, MAG, RMS, RHS and MDG. In addition one or more of the modules PDP, CDP, PPP may be added. The resulting output from a potential flow problem could consist of velocity, mass flux, pressure coefficients, force and moment coefficients and plot data. Figure 4.6 illustrates the data flow.

#### 4.3.2.3 IC-Update Problem

The IC update problem requires execution of the same modules as the standard potential flow run. However, it is a subsequent run to a standard run and the data bases DIP, MAK and RMS must be saved and available for the IC run. Figure 4.7 illustrates the data flow. Section 6.3 discusses the MEC directives required for an IC update run. The IC update capability is described in section 7.2.3.

#### 4.3.2.4 Solution - Update Problem

The solution update problem executes the modules MEC, DIP, RHS, MDG, PDP and CDP. This type of run finds solutions for the original panel geometry with new right-hand-side constraints. The plotting preparation module PPP is optional. Data bases DIP, DQG, MAK and RMS must be saved from a previous

run. Figure 4.8 illustrates the data flow. Section 6.3 discusses the MEC directives for this type of run. The solution update capability is described in section 7.2.3.

#### 4.3.2.5 Additional Post-Solution Problem

Once a potential flow problem has been run, additional data processing and plotting may be requested provided that the data bases from DIP and MDG have been saved. The DIP module does not have to be run again provided all output requests from PDP, CDP and PPP have been anticipated in the first standard run. Otherwise, the DIP module will have to be executed again for a post-processing run. Having the data bases for DIP and MDG available, the user may select some combination of the modules PDP, CDP, and/or PPP. Figure 4.9 indicates the sequence of computation. Section 6.3 discusses the MEC directives required to set up a Post Solution Run. The post-processing run, including optional updating of the DIP data base, is described in section 7.2.3.

#### 4.3.2.6 Non-Standard Runs

Non-standard runs of the PAN AIR system may be introduced with the executive commands of the MEC module. These commands allow the user to execute any existing module, use existing data bases and introduce any legitimate control card into the control card stream. Section 6.0 describes the MEC commands.

### 4.3.3 Accessing Data Produced by PAN AIR

#### 4.3.3.1 Use of Data Bases

Each of the PAN AIR modules generates and maintains one or more data bases for use by subsequent modules. Saving or purging the appropriate data bases is controlled by the user directives to the MEC (Module Execution Control) module. Figure 4.10 illustrates the use of the data bases and their creation sequence. The table should be read by row. Row 1 shows that the DIP data base was created. Row 4 shows that the RMS module does not need the DIP, DQG or MAK databases, but it uses the MAK database and creates the RMS data base.

Data base integrity is maintained by the SDMS module and the status of each data base (whether usable or not) is maintained by each module.

For those users who require additional output beyond what has been provided by the options available in PAN AIR, the information is usually available from one or more of the databases. To access a database created by a PAN AIR run, the user will have to write a FORTRAN program. An example of such a program is given in the PAN AIR Maintenance Document, in appendix 1-B.

#### 4.3.3.2 Use of PAN AIR Plot Data File

The post-processing module PPP generates a formatted plot file that can be used by appropriate plotting software external to PAN AIR. The contents of this plot file depends on the user directives and consists usually of three groups of data:

1. limited configuration geometry data,
2. surface and wake flow pressure and velocity data, and
3. forces and moments data.

The geometry data is derived from the DQG data base. PPP retrieves the pressure and velocity data from the PDP data base and the forces and moments data from the CDP data base selectively as dictated by the user directives.

## 4.4 Module Execution Control

### 4.4.1 PAN AIR System Execution Philosophy

The modules of the PAN AIR software system must be run in a particular order to solve each problem. Each module requires large amounts of input data from previous calculations, other modules or raw data. To simplify the use of the system some special constraints were imposed on the design. The use of databases for data communication between and within modules is intended to alleviate the problems of dealing with massive amounts of input and output data. While these problems are solved very satisfactorily by this approach, a few complications are also introduced. The purpose of the MEC module is to simplify these complications so that the user who desires to run PAN AIR in a straightforward fashion may do so with minimal concern for the more esoteric aspects of file handling and control cards.

There are two complications which arise because of the design constraints. First since each module is a separate program, appropriate control cards must be provided to assure that each program is executed in the proper order to solve the problem. Secondly, the database system, SDMS, generates four files for each database that is created during the execution of PAN AIR. This creates a file management problem.

Due to these complications the number of control cards required for even a fairly simple execution of PAN AIR can easily exceed one hundred, especially if suitable comments are included in the deck. It would be impractical for a user to supply such a deck of cards. To ease this problem, the MEC module automatically creates control cards to run the PAN AIR system from a small number of user problem definition directives. These control cards take care of both the execution of PAN AIR modules in correct sequence and the management of the database files which are created during execution. (Note that with regard to managing the databases created by a PAN AIR run, the system design philosophy is such that any databases which are not needed for execution of the remaining modules are purged. If any of the databases are

required by the user for some special purpose, the user must supply MEC with appropriate directives to save those databases which are required. Section 6 discusses in detail the appropriate user problem definition directives.)

The overall system architecture is depicted in figure 4.11. Data flow procedes generally from left to right. The MEC module produces printed output of user directives and control cards, creates a control card file for execution and creates a data base for the other modules. The DIP module uses the MEC data base and reads in the raw input data for the posed PAN AIR problem. The DIP module outputs the input data card image and a data base for the other modules. The PPP module used for print and plot preparation in conjunction with DIP and the other modules produces a tape used for plotting purposes.

The MEC data base contains the run identification information and data base information of the other module data bases. Information such as data base names, account and identification numbers of the files containing the data bases, passwords and type are stored. Also, database status information such as existing or not, used or not used and saved or not-saved are stored. This information is used to decide which data bases should be purged to save disk space.

### 4.4.2 The MEC Module

#### 4.4.2.1 Purpose

The MEC module creates a file of control cards and data base information based upon the user posed PAN AIR problem.

#### 4.4.2.2 Tasks Performed

A data base is created for use by other PAN AIR modules. It contains data base information on data bases used or created by the other modules. Run identification is also processed and stored in the data base. Codes are set to indicate whether data bases are used, in existence or saved.

User directives for modifying the data base information table are processed by MEC and appropriate modifications to the MEC data base are made.

User directives for defining the PAN AIR problem are also interpreted and processed. As a result of these directives, a file of control cards is created which will solve the specified PAN AIR problem.

#### 4.4.2.3 Input Data

User directives are supplied to MEC via cards and or card images. The cards contain run identification information, data base directives, problem definition directives and control card information.

#### 4.4.2.4 Output Data

The output consists of the data base information table, the card images used for input, a printout of the generated control card file and error diagnostics. Section 8.5 contains examples of the output from MEC.

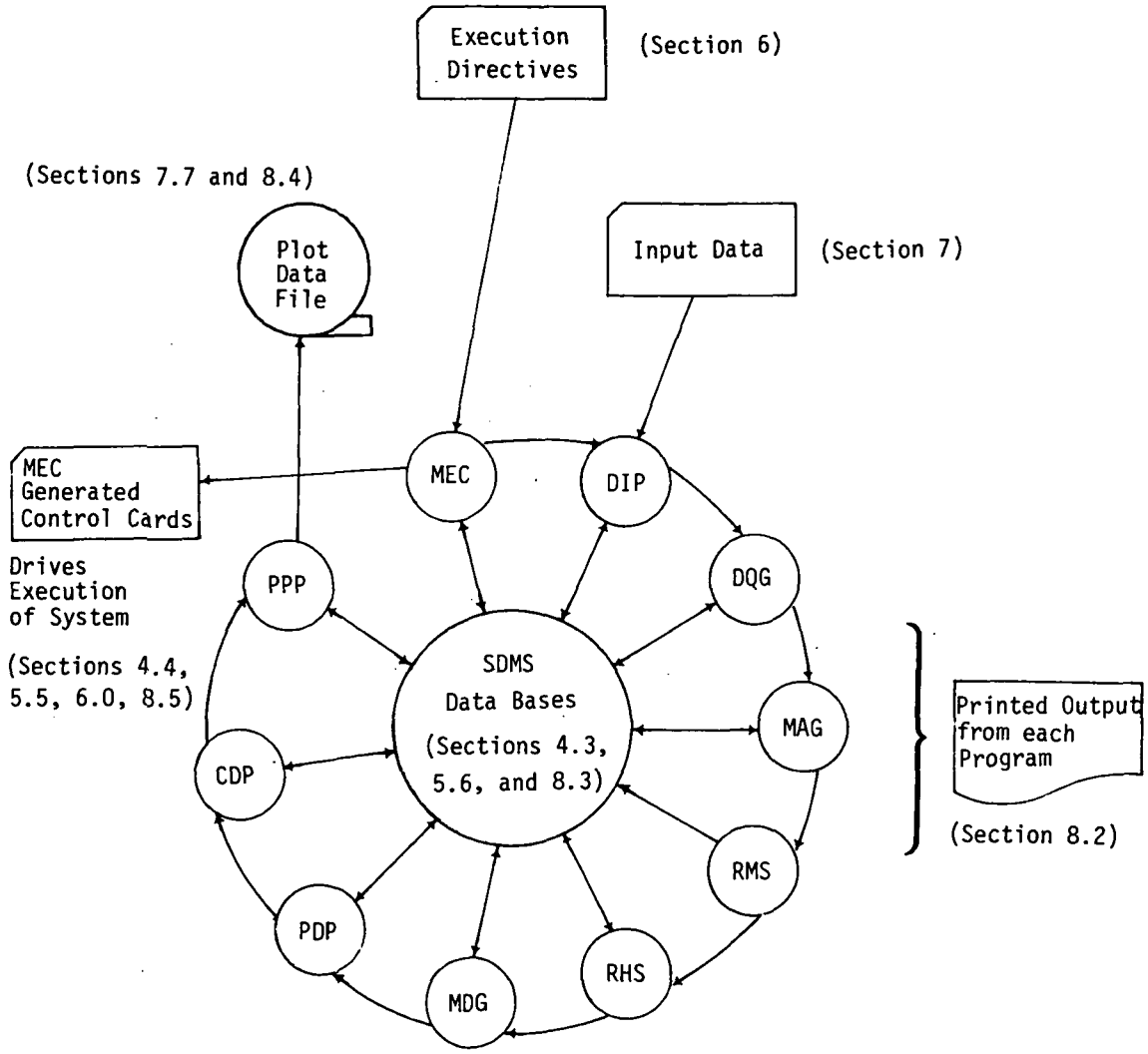



Figure 4.1 - Relation of PAN AIR Modules, Data Bases, and External Input/Output

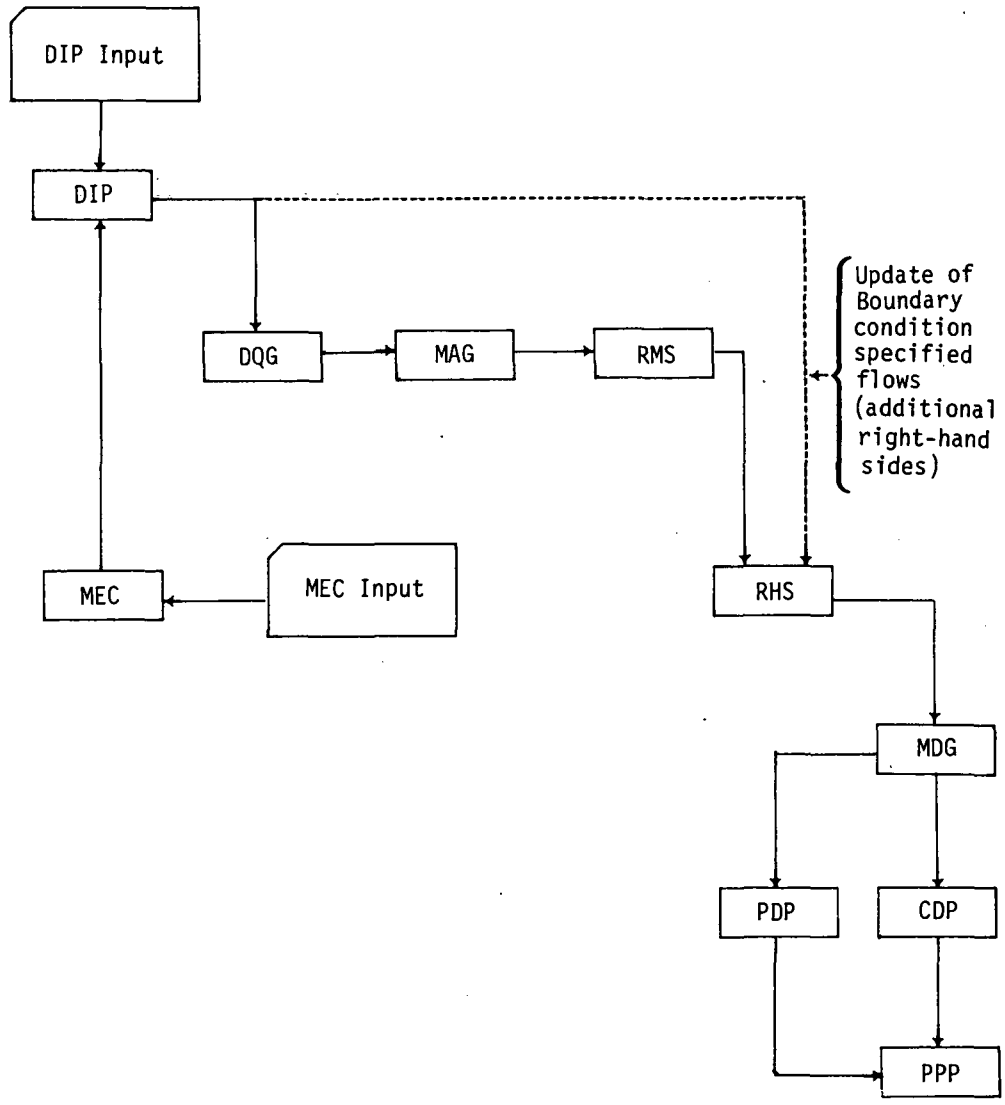



Figure 4.2 - Standard Execution Sequences of PAN AIR Modules

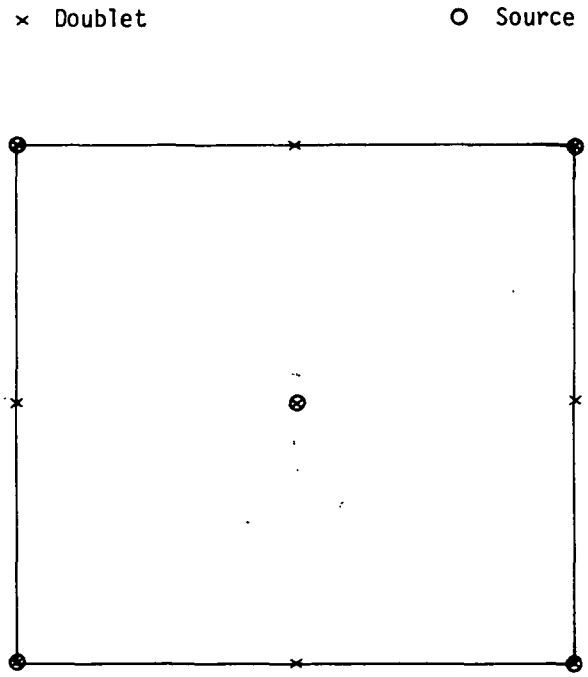



Figure 4.3 - Panel points at which doublet and source strengths are defined by DQG-produced spline vectors

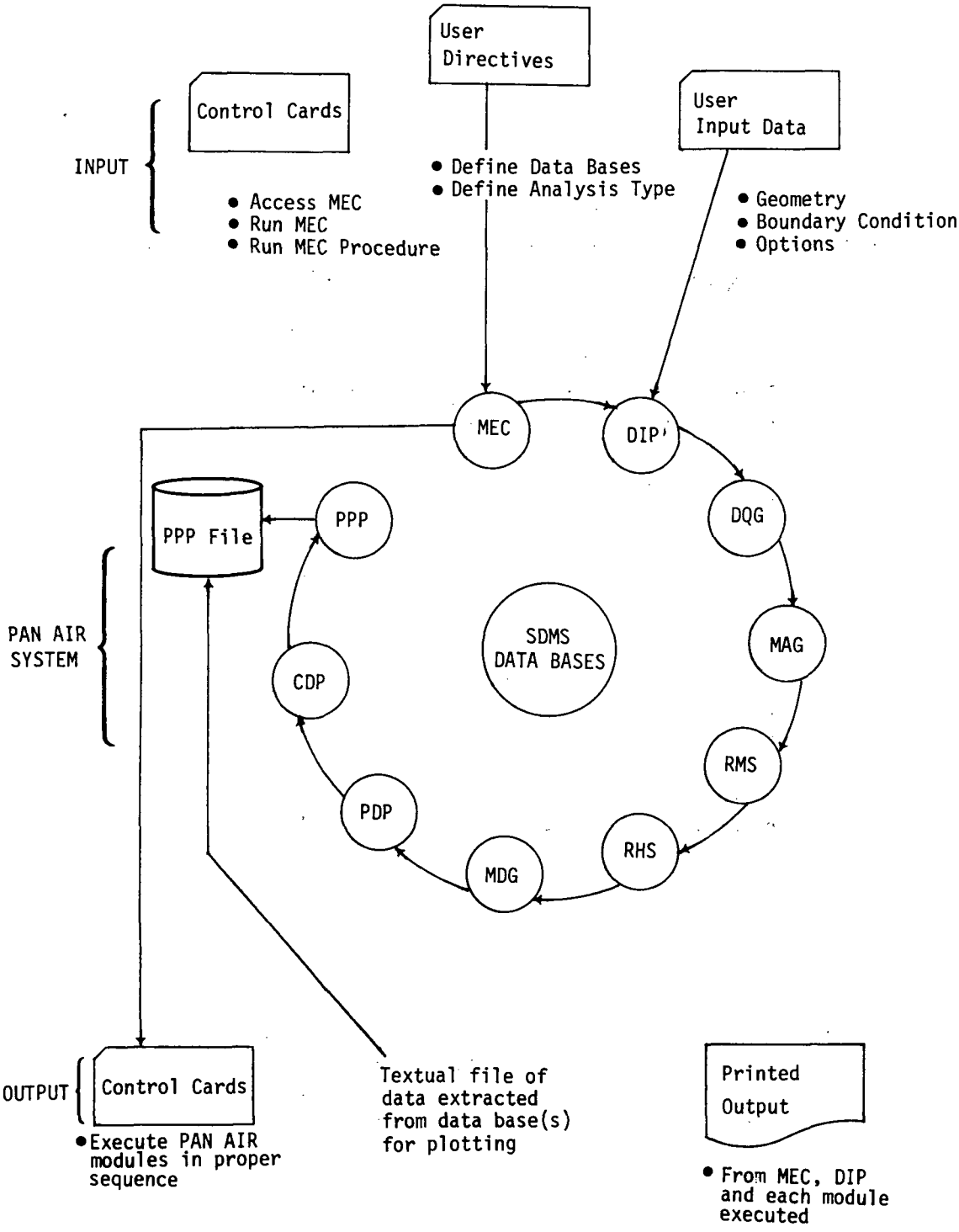



Figure 4.4 - Modes of Input/Output

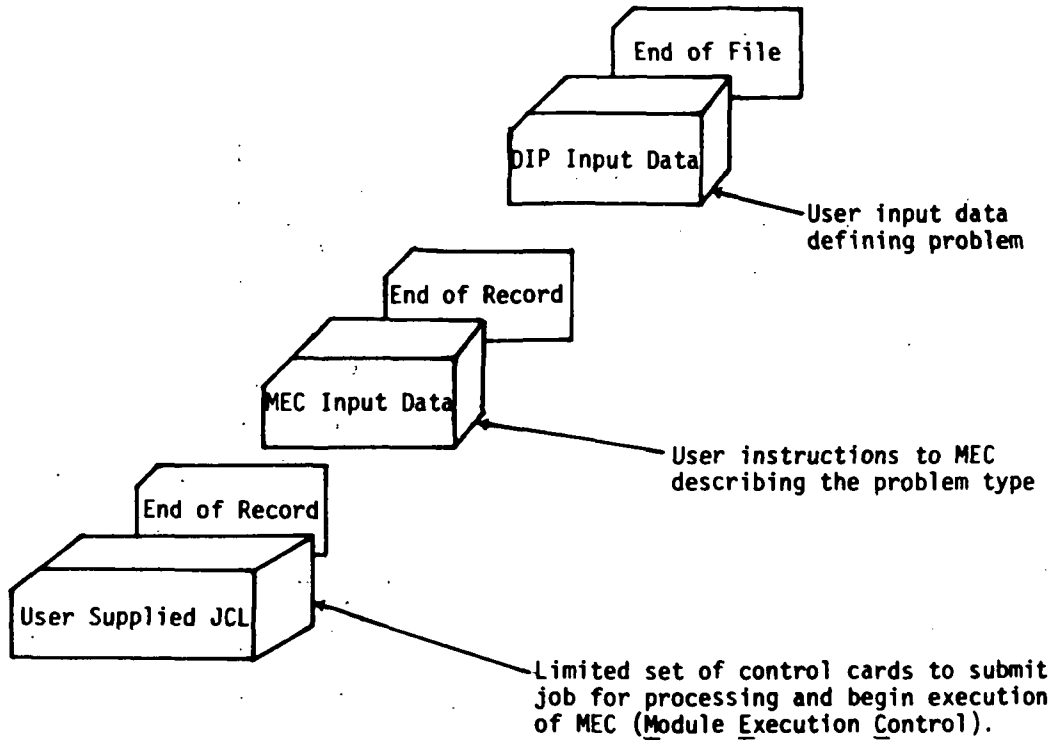



Figure 4.5 - Deck to Submit PAN AIR

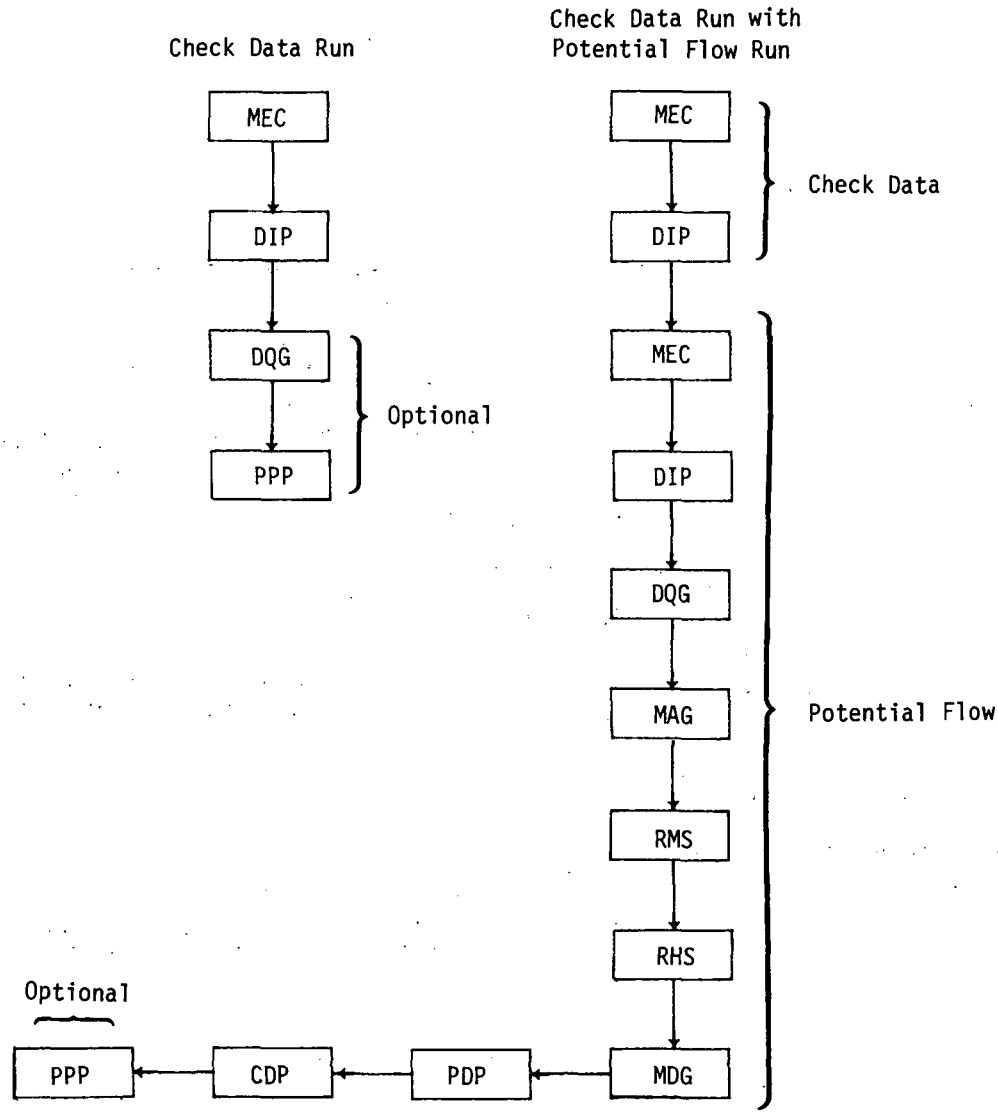



Figure 4.6 - Check Data and Potential Flow Run

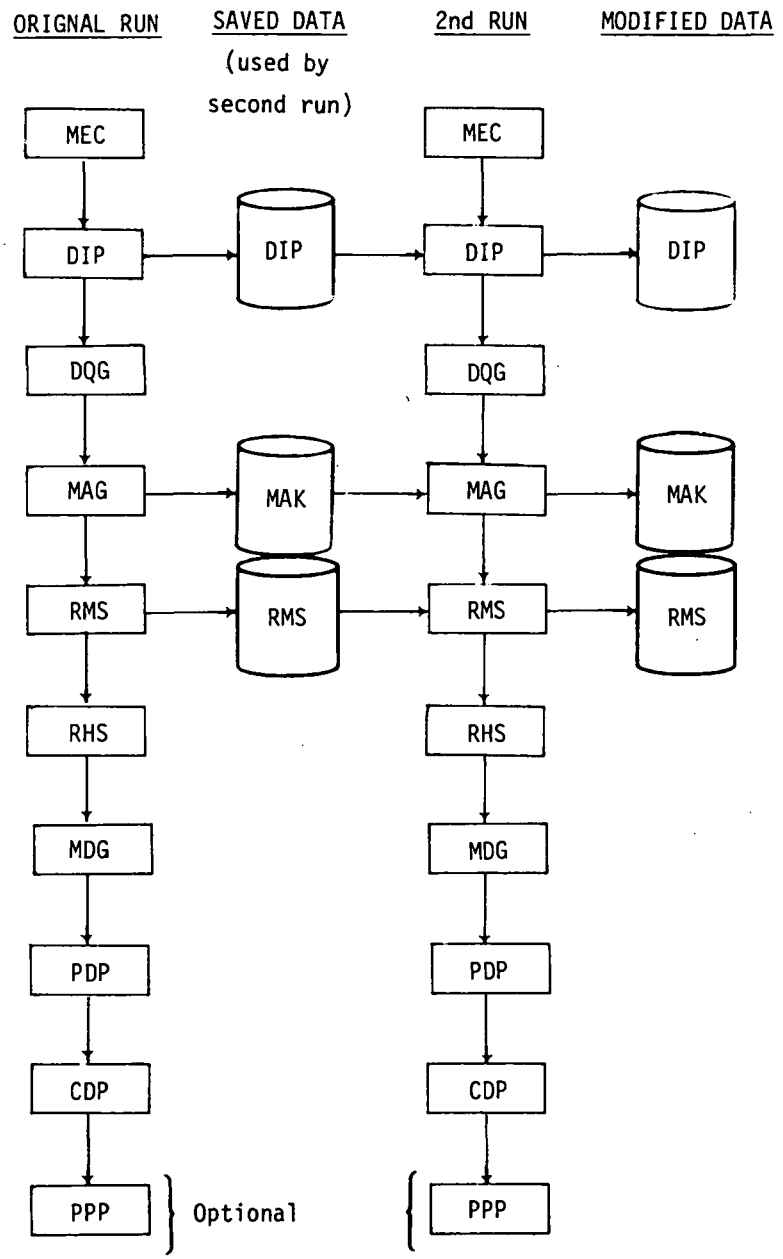



Figure 4.7 - IC Update Run

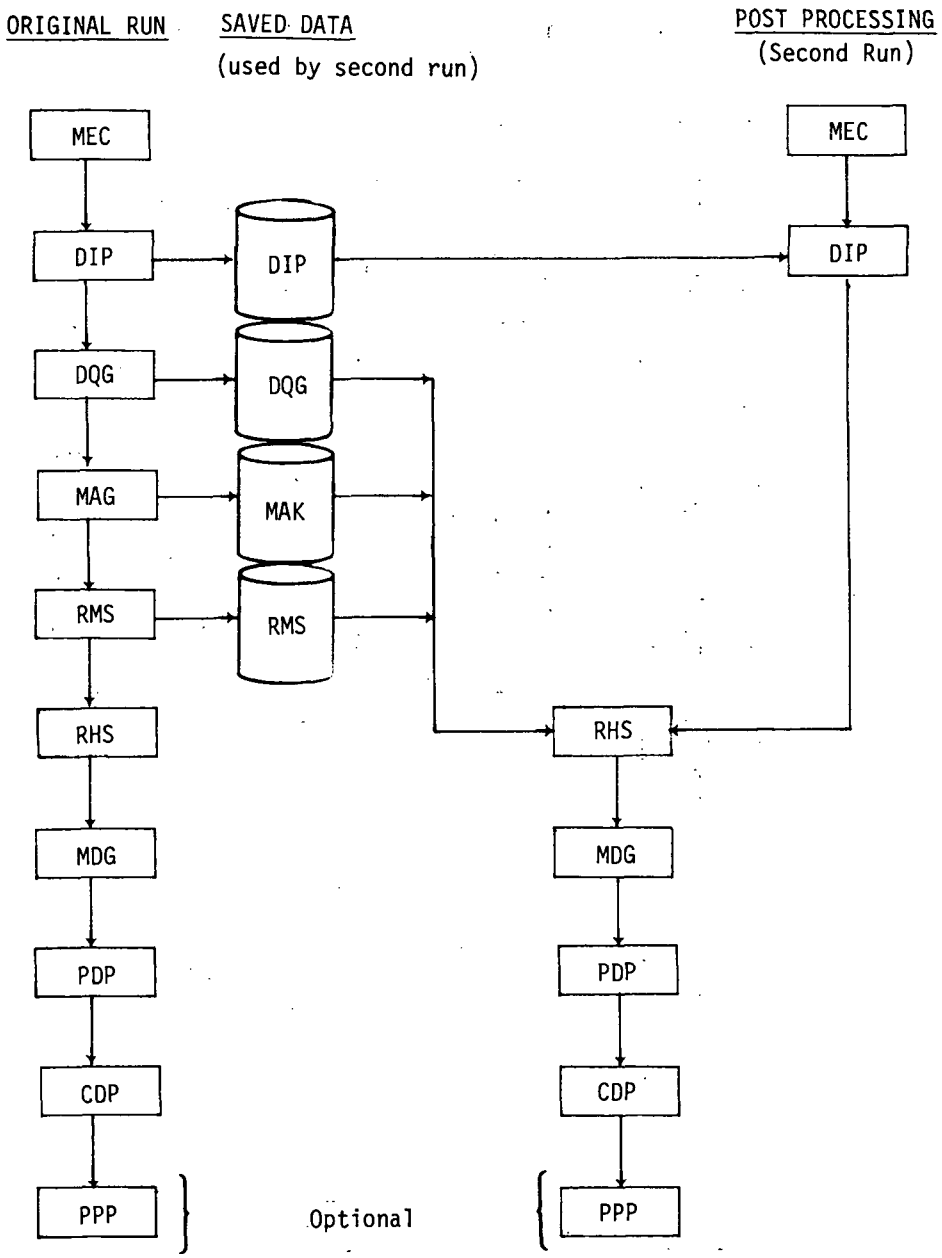



Figure 4.8 - Solution Update Run

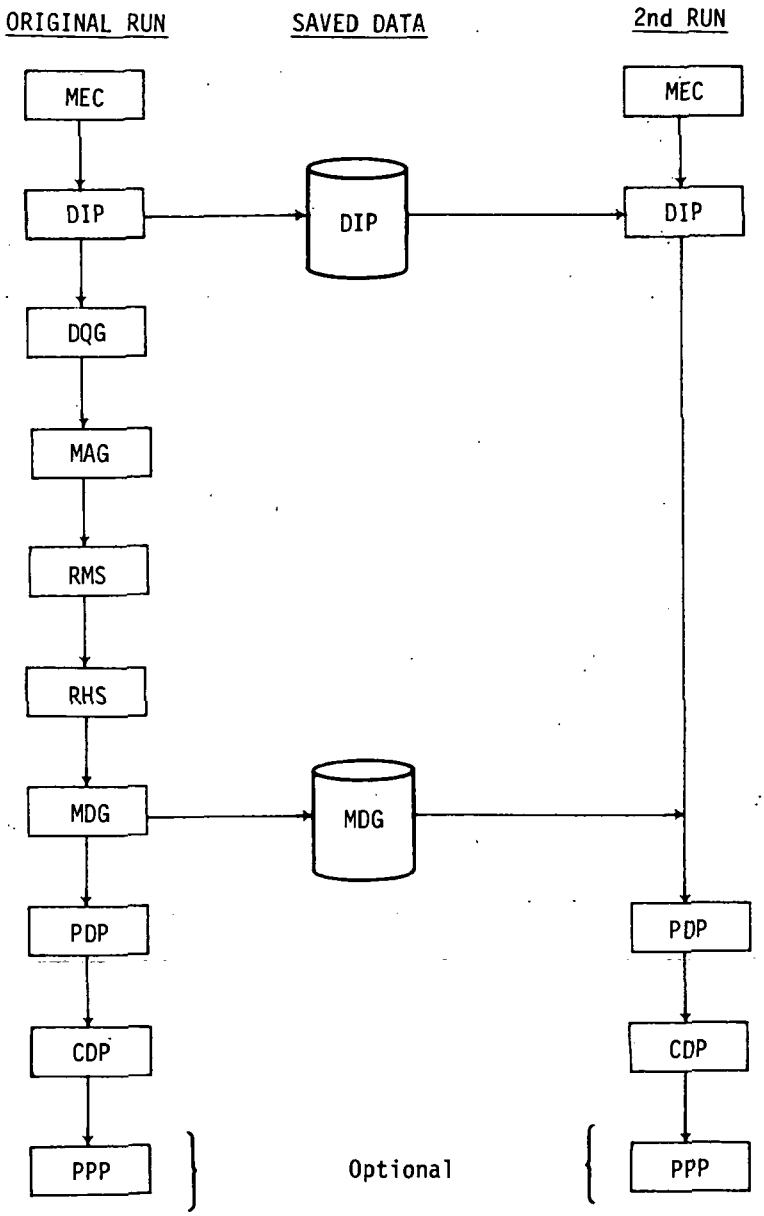



Figure 4.9 - Additional Post Processing

| Module | Databases | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | DIP | DQG | MAK | RMS | RHS | MDG | PDP | CDP | OFB |
| DIP | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| DQG | 2 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| MAG | 0 | 2 | 1 | 0 | 0 | 0 | 0 | 0 | 0 |
| RMS | 0 | 0 | 2 | 1 | 0 | 0 | 0 | 0 | 0 |
| RHS | 2 | 2 | 2 | 4 | 1 | 0 | 0 | 0 | 0 |
| MDG | 0 | 3 | 4 | 0 | 3 | 1 | 0 | 0 | 0 |
| PDP | 2 | 0 | 0 | 0 | 0 | 2 | 1 | 0 | 0 |
| CDP | 2 | 0 | 0 | 0 | 0 | 4 | 0 | 1 | 0 |
| PPP | 4 | 4 | 0 | 0 | 4 | 0 | 4 | 4 | 4 |

Codes

0 - Not used or not created

1 - Created

2 - Used

3 - Not needed thereafter unless PPP was requested or a save has been issued

4 - Not needed thereafter unless requested for a save

Figure 4.10 - Permanent data bases

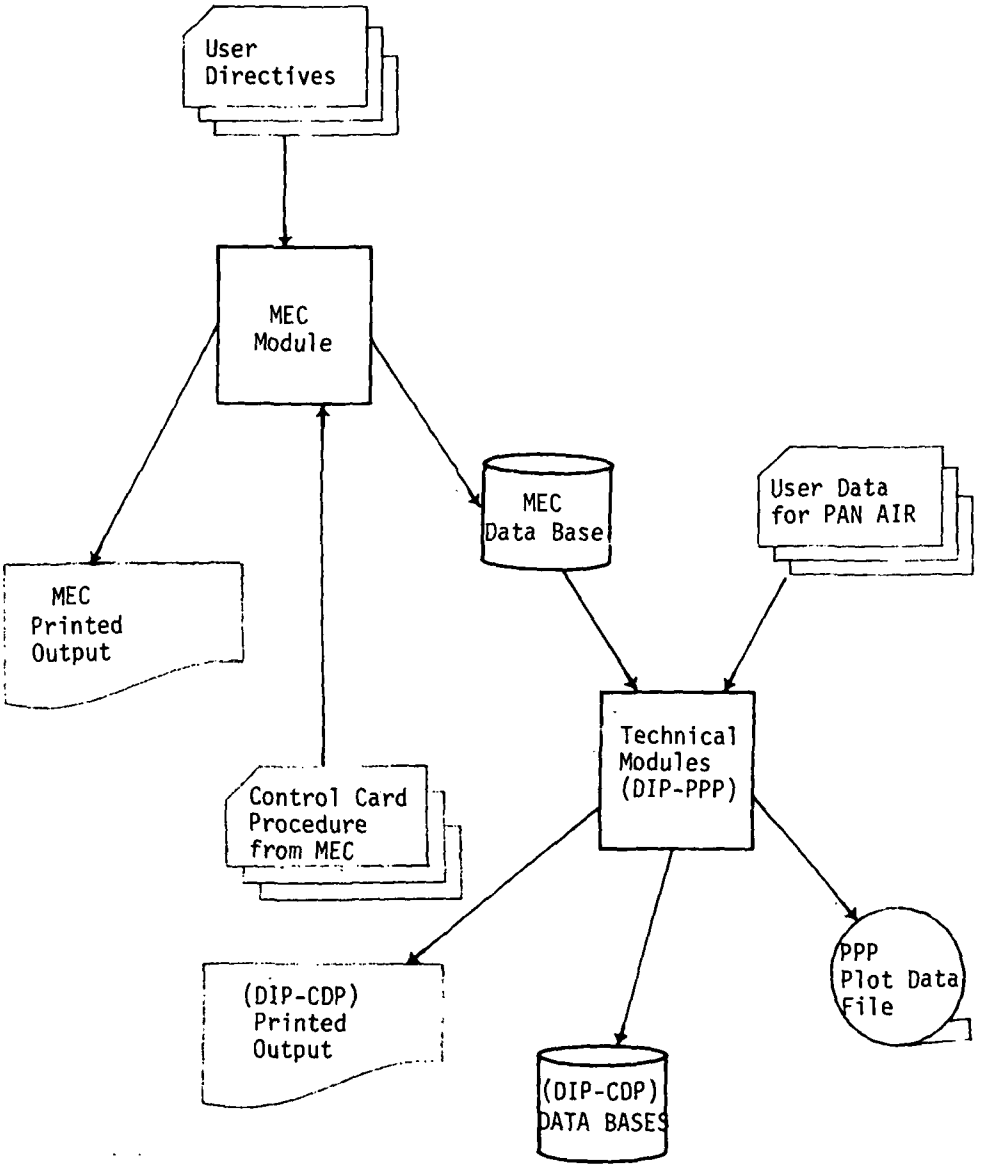



Figure 4.11 - PAN AIR System Architecture

# 5.0 System Usage

## 5.1 Usage Overview

The PAN AIR software system can be accessed either through cards or a card image input file. Figure 4.5 illustrates the overall deck structure of a PAN AIR run. The DIP module accepts input from cards in the input file or from a local file defined by the user in the MEC input data.

## 5.2 The Job Control Cards JCL for Initiation of PAN AIR

The description of the user supplied and system supplied control cards is complicated by the various user computer installations and the different operating systems. There are basically four different combinations of installations and operating systems that PAN AIR was installed on prior to general release. They are described in Table 5.1. The user supplied JCL and the system supplied JCL are defined separately for the three different combinations.

### 5.2.1 NOS 1.2 JCL (Boeing Installation)

#### 5.2.1.1 User Supplied JCL

In order to initiate the PAN AIR software, the user must supply the following cards:

```
jobname, Ttt,CMfl.
USER,username, pw.
ATTACH,PANPRC/UN=name.
CALL,PANPRC,RUN(NAME=name)
```

| | | |
|---|---|---|
| where | tt | is the CPU time needed e.g., 100, |
| | fl | is the central memory needed e.g., 130000, |
| | username | is the user account number, |
| | pw | is the password for username, |
| | PANPRC | is the procedure file containing job control cards to execute PAN AIR |
| and | name | is the account number where all PAN AIR programs and data base master definition files reside. |

Once executed, these cards will access a procedure file stored with the PAN AIR software system. The contents of this procedure file is described in the next section.

5.2.1.2 PAN AIR Supplied JCL

The set of procedure cards stored with the PAN AIR software system and used to access the MEC module is as follows:

```
COMMENT.*** THE FOLLOWING CARDS ARE THE PANPRC PROCEDURE***
RUN.
COMMENT.
COMMENT. *** ACQUIRE MEC***
COMMENT.
ATTACH, MEC/UN=name.
MEC.
RETURN,MEC.
COMMENT. ** MEC PUTS ***
COMMENT. *** CONTROL CARDS ON ***
COMMENT. *** FILE MECCC ***
COMMENT.
REWIND,MECCC.
COMMENT.
COMMENT. *** EXECUTE PROCEDURE ***
COMMENT. *** ON MECCC ***
COMMENT.
CALL,MECCC,MECCC(UN=name).
EXIT,C.
COMMENT.
COMMENT. *** END OF PANPRC PROCEDURE ***
COMMENT.
```

It should be noted that "name" in the above JCL is the same as "name" in the JCL in the previous section (5.2.1.1), "name" being the account number where all PAN AIR program modules and data base master definition files reside.

5.2.2 NOS 1.2 JCL (NASA Langley Installation)

5.2.2.1 User Supplied JCL

```
jobname, Ttt, cmfl.
Account, username, pw.
CHARGE(nnnnnn, LRC)
PACKNAM(packname)
ATTACH,PANPRC/UN=name.
CALL,PANPRC,RUN(NAME=name)
```

where nnnnnn and LRC are the parameters required by the installation for accounting purposes,

packname is disk-pack name (serial number) assigned to the user where PAN AIR resides.

and the other parameters have the same meaning as described in section 5.2.1.1.

5.2.2.2 PAN AIR Supplied JCL

This set of JCL is the same as that given in section 5.2.1.2. All differences between the NOS 1.2 Boeing installation and NASA Langley installation are recognized by the MEC module and thus accomodated in MEC generated control card file "MECCC".

5.2.3 NOS/BE JCL (Wright Patterson Air Force Base Installation)

5.2.3.1 User Supplied JCL

The following cards must be supplied by the user to begin execution of the PAN AIR software system:

```
jobname,Ttt,CMfl,IOnnnn.account
ATTACH,PANPRC,ID=name.
BEGIN,RUN,PANPRC,name,sn.
```

| | | |
|---|---|---|
| where | nnnn | is the I/O time needed, |
| | account | is the user account number, |
| | name | is the identification (ID) for all PAN AIR programs and master definition files |
| and | sn | is the setname of disk unit assigned to the user account. |

These cards will call upon a JCL procedure file ("PANPRC") stored with the PAN AIR software system which will continue processing.

5.2.3.2 System Supplied Control Cards

The set of procedure cards stored with the PAN AIR software system used to access the MEC module and continue execution is as follows:

```
.PROC,RUN,name,sn.
COMMENT.
COMMENT. *** THE PANPAC PROCEDURE FOLLOWS ***
COMMENT.
ATTACH,MEC,ID=name,SN=sn.
MEC.
RETURN,MEC.
COMMENT.
COMMENT. *** A SYSTEM PROCEDURE ON FILE MECCC ***
COMMENT. *** IS CREATED BY MEC ***
COMMENT.
REWIND,MECCC.
BEGIN,MECCC,MECCC,name,sn.
EXIT,C.
COMMENT.
COMMENT. *** END OF PANPRC PROCEDURE ***
COMMENT.
REVERT.
```

### 5.2.4 Scope 2.1.3 JCL (NASA Ames Installation)

The user must supply the following JCL cards to initiate execution of the MEC module, which in turn, generates a local file named MECCC from which the user obtains the remaining JCL cards for a PAN AIR run. The MECCC file contains two JCL procedure cards, the first and the last. They must be removed manually and the remaining cards are placed after the same set used to obtain them in the first place.

FIRST RUN

```
jobname,Ttt,CMfl,YDn,YLm.
ACCOUNT,username,account.
SETNAME(sn)
MOUNT,VSN=vsn,SN=sn.
ATTACH,MEC,ID=name,SN=sn.
MEC.
RETURN,MEC.
COMMENT.
COMMENT. *** A SYSTEM PROCEDURE ON FILE MECCC ***
COMMENT. *** IS CREATED BY MEC ***
COMMENT.
REWIND,MECCC.
DISPOSE, MECCC,PH.
```

The last control card punches out the file MECCC.

SUBSEQUENT RUN

```
jobname,Ttt,CMfl,YDn,YLm.
ACCOUNT,username,account.
SETNAME(sn)
MOUNT,VSN=vsn,SN=sn.
ATTACH,MEC,ID=name,SN=sn.
MEC.
RETURN,MEC.
COMMENT.
COMMENT. *** A SYSTEM PROCEDURE ON FILE MECCC *
COMMENT. *** IS CREATED BY MEC ***
COMMENT.
REWIND,MECCC.
*DISPOSE,MECCC,PU
Control  ----*.PROC,MECCC.
Cards          COMMENT.
Provided       COMMENT.   ***   EXECUTE DIP.   ***
by             .
MEC on         .
file MECCC     .
by             EXIT.
first    ----*REVERT.
run
```

*These cards must be removed for the second run.

where n is the number of disk drives needed (e.g., YD2),
m is the number of logical mounts needed (e.g., YL37)
vsn is the volume serial number of the disk unit (master disk).
sn is the setname of the disk unit.

## 5.3 Data Base Generation

Most PAN AIR modules produce data bases which allow communication between program modules and within program modules. Figure 5.1 illustrates the data base creation process and indicates the contents of the data stored in the various data bases.

## 5.4 Resource Requirements

### 5.4.1 CPU Time Requirements

Table 5.2 summarizes the CPU timing estimates for the CYBER 175 computer. The numbers are only estimates and will generally vary from problem to problem.

### 5.4.2 Core Requirements

Table 5.3 gives the core requirements for the PAN AIR modules. It will be noted that the existing modules require less than 130,000 octal words.

### 5.4.3 Disk Requirements

The disk storage requirements will vary greatly from problem to problem.

The permanent and temporary data bases expand or contract as the modules execute. Table 5.4 gives the known disk requirements for four validation cases defined in the PAN AIR Case Manual.

For large problems, the user must provide sufficient disk space for PAN AIR to run successfully. For installations which allow removable disk packs, it is advisable to set up a set of two or more disk units. For other installations, the user must acquire enough disk space (permanent file storage) for PAN AIR to execute successfully.

## 5.5 Modes of Execution

The PAN AIR software system is designed to run on CDC operating systems SCOPE 2.1.3, SCOPE 3.4, NOS 1.2 and NOS/BE. The MEC module produces the required control cards automatically for the operating system in use.

### 5.5.1 Standard Runs

There are five types of standard runs: check data run, potential flow run and the three types of update runs. The check data run allows the user to check MEC and DIP module input data before execution other modules. The check run also has options to continue with execution of DQG or both DQG and PPP for further checks on the input data. The potential flow run executes MEC, DIP, DQG, RMS, RHS, MDG and PDP (plus CDP and PPP on option). The update runs are either "left-hand side," "right-hand side" or "post-solution". A left-hand side update (IC UPDATE) requires recomputation of portions of the aerodynamic influence coefficient matrix. A right-hand side update (SOLUTION UPDATE) allows the introduction of new solutions or changes in existing solution data. A post-solution update (POST PROCESSING UPDATE) allows the specification of flow properties calculations. The update capabilities are described in more detail in section 7.2.3.

Section 6 discusses the MEC input necessary to execute each of the standard runs. Section 4.3.2 describes these runs in more detail.

### 5.5.2 Non-Standard Runs

Non-standard runs are all other PAN AIR problems in which the user may construct his own control card stream using streamlined MEC commands. Section 6 discusses all MEC directives and section 6.3 provides some examples of the use of MEC directives in non-standard runs, e.g., additional post processing runs.

### 5.5.3 Running PAN AIR on Non-Standard Operating Systems

As originally constructed PAN AIR will run on CDC machines (CDC 6600, CDC Cyber 175 and CDC 7600) under three operating systems (NOS 1.2, NOS/BE and SCOPE 2.1.3). Future expansion may allow modifications to extend use to other machines or operating systems.

There are two areas of the system which are sensitive to the details of the operating system. They are the database management system (SDMS) and the Module Execution Control (MEC). SDMS is closely coupled to the operating system because it is responsible for the execution of most disk I/O during PAN AIR execution. MEC is sensitive to operating system differences since it provides the set of control cards which simplifies the user's task of running the job.

At many installations which share the same operating system there are variations in implementation which sometimes causes some control cards which are acceptable at one installation to fail to work correctly at another. For this reason it may be the case that the MEC generated control cards might fail to work correctly at some installation other than Boeing, NASA/Langley, NASA/Ames or Wright-Patterson AFB even though the installation is using an implementation of one of the three standard operating systems (NOS 1.2, NOS/BE and SCOPE 2.1.3).

If a user finds such a situation to correspond to his case, it will still be possible to run PAN AIR but the user may have to accept responsibility for preparing his own control cards to execute PAN AIR. In such a case the user is advised to study the control cards provided by MEC (perhaps in consultation with representatives of his computer installation) to determine what modifications are required to the control card file to allow proper execution on the user's system.

The modifications may be made either by adding or changing the indicated cards manually or by modifying the program MEC to produce the required control cards. Note that if MEC (or any other modules or libraries in the PAN AIR system) is modified by users for special purposes, the maintenance organization for PAN AIR will probably not support such modifications unless the changes occur through the standardized Change Request format. (See PAN *AIR System Configuration Control Procedures Manual.*)

## 5.6 Saving and Reusing Data

The PAN AIR software system automatically purges unneeded data bases in order to conserve disk space. If an update, IC run or post processing run is to be executed in the future, it is up to the user to save the required data bases through the use of appropriate MEC module directives. The same is true for other non-standard runs requiring data bases previously generated.

| Location | Operating System | Computer Hardware | Removable Disk Pack$_\mu$ | Catalogued Procedure$_\mu$ |
|---|---|---|---|---|
| Boeing | NOS 1.2 | Cyber 175 | No | Yes |
| NASA Langley | NOS 1.3 | Cyber 175 | Yes | Yes |
| NASA Ames | SCOPE 2.1.3 | CDC 7600 | Yes | No |
| Wright Patterson AFB | NOS/BE | Cyber 74 | No | Yes |

Table 5.1 - Installation considerations at locations where PAN AIR was first installed

| Module | Case1 | Case2 | Case3 | Case6 |
|---|---|---|---|---|
| MEC | .1 | .1 | .1 | .1 |
| DIP | .33 | .43 | .98 | 1.2 |
| DQG | 2. | 9. | 106.7 | 48. |
| MAG | 1.45 | 18.2 | 314. | 55.8 |
| RMS | .6 | .62 | 33.2 | 8.5 |
| RHS | 1.33 | 6.3 | 16.9 | 13.6 |
| MDG | 1.98 | 7.2 | 39.8 | 8.5 |
| PDP | 1.78 | 3.5 | 8.9 | 8. |
| CDP | 1.03 | 1.3 | 8. | 7. |
| PPP | 1.07 | 1.41 | 9. | 8. |

Table 5.2 - Validation case CPU time requirements (sec) (NASA Ames CDC 7600)

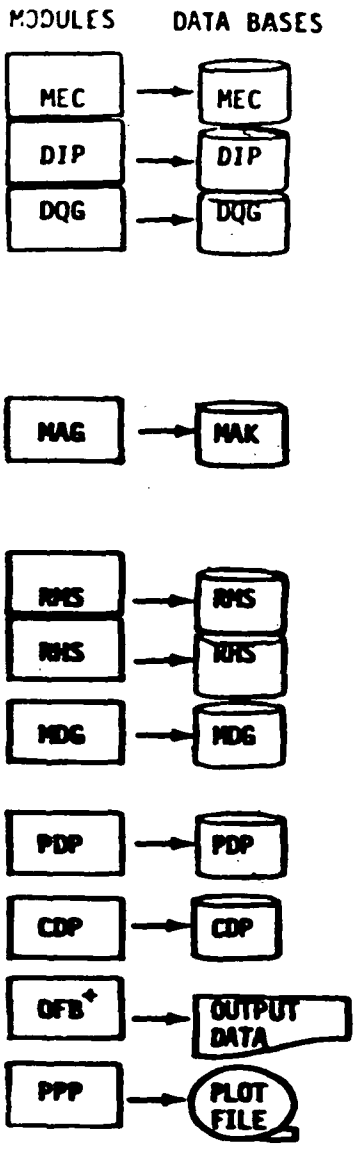
| Module | CDC 6600 $(*1000\ words)_8$ | CDC 7600 $(*1000\ words)_8$ |
|---|---|---|
| MEC | 70 | 45 |
| DIP | 103 | 67 |
| DQG | 127 | 74 |
| MAG | 130 | 112 |
| RMS | 110 | 62 |
| RHS | 100 | 51 |
| MDG | 125 | 75 |
| PDP | 110 | 60 |
| CDP | 112 | 60 |
| PPP | 110 | 60 |

Table 5.3 Core requirements for each module

Disk Requirements CDC 7600 (Words)

| Module | Case 1 | Case 2 | Case 3 | Case 6 |
|---|---|---|---|---|
| MEC | 1,800 | 1,800 | 1,800 | 1,800 |
| DIP | 17,300 | 18,900 | 20,600 | 18,200 |
| DQG | 257,200 | 651,600 | 493,600 | 975,600 |
| MAG | 161,700 | 321,149 | 735,800 | 975,600 |
| RMS | 17,200 | 128,815 | 89,200 | 104,900 |
| RHS | 13,600 | 68,220 | 71,300 | 41,700 |
| MDG | 30,600 | 68,367 | 91,600 | 69,800 |
| PDP | 60,000 | 130,000 | 160,000 | 700,000 |
| CDP | 7,000 | 35,000 | 40,000 | 36,000 |
| PPP | 4,000 | 25,000 | 30,000 | 24,000 |

Table 5.4 Validation case disk storage requirements (CDC 7600 words)




MODULES AND THEIR PURPOSE

MEC generates control cards for problem

DIP interprets user input

DQG generates panel defining quantities plus data for control points, boundary conditions and singularities

AIC MAG creates Aerodynamic Influence Coefficients Unknown Singularity Portion

AIC MAG creates Aerodynamic Influence Coefficients Known Singularity Portion

IC MAG computes Influence Coefficients

RMS Decomposes AIC unknown

RMS processes singularities and boundary condition data

MDG finds average potential velocity and normal mass flux at control and grid points plus DQG geometry

PDP computes potential, velocity, normal mass flux, and pressures for selected surfaces

CDP computes forces and moments accumulated over portions of congifuration

OFB computes potential, velocity, normal mass lux and locations off configuration

PPP selects data formatted for external display processing

\+ Not available for Version 1.0

Figure 5.1 - Program Modules and Data Bases

## 6.0 MEC Input Data (User Directives)

The MEC module interprets user supplied PAN AIR problem definitions in a very general input language, supplies the job control cards (JCL) required to solve the posed problem and provides detailed information concerning the names and identification parameters of the database files.

Previous sections of this document have discussed the standard and non-standard problem types (see section 5) and the user provided control cards required to run the PAN AIR system. Before presenting a detailed discussion of MEC directives it is necessary to discuss some labeling information regarding the database files.

SDMS defines four files for each database. The files are distinguished from one another by appending the number 1, 2, 3 or 4 to the database name. SDMS performs this automatically. The PAN AIR system provides a set of default database names (e.g., DIP, DQG, MAK). Thus if the default database name is used, after execution of the DIP module, there will exist four permanent files with names DIP1, DIP2, DIP3 and DIP4.

If a user solves more than one aerodynamic problem at the same time (with separate runs) with PAN AIR, it is necessary to have distinct names for the database files. MEC provides convenient ways to name the database files with something other than the default name. The user may rename one or more databases by appending to any of the default names a sequence of up to three characters. Alternatively the user may rename a database with some arbitrary sequence of up to six characters.

In addition to names for the database files, permanent files also require a particular account or user identifier. MEC directives allow the user to define these account numbers or user identifiers. Finally if the operating system allows the use of removable disk packs, SDMS must be told which pack (setname) to use. This is also accomplished by an appropriate MEC directive.

A simple input example for MEC is given below. The non-indented cards of the example are the major card separators of the MEC input cards. The order is important and must be used. Each of the cards will be discussed in detail after a few preliminary definitions are made.

```
PAN AIR                              - Needed for all installations
SYSTEM PANAIR FAEBRP2 AMES           - For AMES operating system
RID:  SQUARE WING 2X2 PANELING       - Run identification
DATA BASE DIRECTIVE BLOCK            - specific data base information
     APPEND A1 TO DIP                - relabel default database names
     UID = FAELLE FOR MDG, CDP       - specify user ID for MDG and CDP
                                       database files
     MUID = PANAIR FOR ALL           - specify user ID for master definition
                                       files
     MSET = FAEBRP2 FOR ALL          - specify setname of disk where master
                                       definition files reside
END DATA BASE INFORMATION            - Last card of data base information
CHECK DATA RUN                       - Checks input data
EXECUTION DIRECTIVE BLOCK            - Defines PAN AIR problem
     FIND POTENTIAL SOLUTION         - Full solution request
END EXECUTION DIRECTIVES             - Last Card of directive block
END OF PAN AIR MEC INPUT             - Last Card of MEC input
```

In this example the user is running on an operating system at or similar to that of NASA/Ames (SCOPE 2.1.3). The database directives indicate that the default datbase for DIP is being relabeled by appending the characters A1 to the default name DIP. Thus the four files created by SDMS which make up the DIP database will be called DIPA11, DIPA12, DIPA13 and DIPA14. All other database files will be called by their default names. The user identifier for the MDG and CDP database files is specified as FAELLE. The setname of the disk which contains the master definition files is specified to be FAEBRP2 and the user identifier for the files is specified to be PANAIR. The "CHECK DATA RUN" card specifies that control cards will be generated to execute module DIP alone to allow the user to verify the input data he has provided is acceptable to DIP. The execution directives indicate that a full potential flow solution is required. The necessary control cards will be generated so that PAN AIR modules DIP through CDP will be run in correct sequence. All database files will be purged at the end of the execution of CDP since the directives to MEC do not specify that any of the database files should be saved.

The rest of this section presents information necessary to the user to prepare MEC directives. Section 6.1 discusses general features of the MEC directives. Section 6.2 presents a detailed discussion of these directives. This section should be regarded as a reference section which the user would consult to find the explicit form for a particular directive. As such, the first-time reader is advised to skip this section. Section 6.3 is a guide to the construction of MEC directives. It is more instructional in format that section 6.2 and should provide the first-time user with an understanding of the use of MEC directives. Section 6.4 discusses the use of MEC and PAN AIR on systems and installations other than the standard ones at Boeing, NASA/Ames, NASA/Langley and Wright-Patterson AFB.

## 6.1 General Rules and Conventions

From the example it is clear that there are three basic sections to the MEC directives. The first (introductory) section specifies the operating system in use and provides a label for the run. The second section describes properties of the database files. The third section defines the set of control cards which MEC will generate for the user.

The minimum input to MEC consists of the PAN AIR card, the SYSTEM card and the END OF PAN AIR card. If this minumum input is chosen, default names and identifiers of database files are selected and no control cards are generated by MEC.

Naturally, the user will wish to provide more than the minimum input in order to simplify the execution of PAN AIR. Section 6.2 describes in detail the various MEC input directives for the three sections. Some examples of MEC input directives are provided in section 6.3.

The following conventions are used to describe the directives of the MEC input module:

- o Required key words are underlined. Note that only the first three or four characters of keywords are recognized.

<> optional item

{ } include one from this list

{{ }} include one or more from this list

- lower case variables indicate that a user supplied name or value should be substituted.
- A comma or a blank may be used to separate key words.

The following abbreviations are used to define operating and MEC system parameters.

uname - PAN AIR software system account number i.e., the account number where all PAN AIR software exists.

sn - The disk pack set name, where the PAN AIR software resides.

## 6.2 MEC Input Directives

In this section a detailed discussion of all MEC directives is presented. Section 6.2.1 discusses the cards in the introductory section. Section 6.2.2 discusses the cards in the database directive part of MEC input. Section 6.2.3 discusses the cards in the execution directive part of MEC input. Note that the CHECK DATA RUN card is included as a part of the introductory section despite the fact that it causes generation of control cards by MEC, a function primarily of directives in the third section of MEC input. This is done primarily to simplify the MEC input for the data check run. Examples of the use of these commands are provided in section 6.3.

### 6.2.1 Introductory Cards

The introductory MEC input cards are discussed in the order they are needed.

PAN AIR labeling information

This is the first MEC input card and must be present. If the card is missing the PAN AIR job will be aborted.

SYSTEM uname sn { BOEING / AMES / LANGLEY / WRIGHT }

The SYSTEM card gains access to the PAN AIR software system. The input "uname" refers to user account number for NOS 1.2 operating system or to user identifier for Scope 2.1 and NOS/BE operating systems. The input parameter "sn" is the set name of a removable disk pack if it is used to store the PAN AIR system. For a discussion of the use of the SYSTEM card at other installations see section 6.5.

RID 76 characters of run identification

The RID card identifies or labels the PAN AIR run being made. This card is optional.

CHECK DATA RUN WITH DQG WITH PLOTS

The optional card CHECK DATA allows the user to execute and check the input data for the DIP module. The optional keyword DQG would execute the DQG module which would check the geometry data as well as the DIP input data. The keyword PLOT would generate control card to execute PPP module to prepare a file of DQG geometry data for purposes of obtaining plots.

### 6.2.2 Data Base Directives

The PAN AIR modules use one or more data bases for input and output. These data bases are stored on disk. As they are created, each needs a master definition or structure. These definitions are stored as part of the PAN AIR software system. Each data base needs a default name, actual name, master definition, account number for the data base, account number for the master definition, password. A disk set name may also be required for the master definitions and the data bases for some operating system which require them, (e.g. NASA/Ames (SCOPE 2.1.3) and Wright-Patterson AFB (NOS/BE)). Tables 6.1 and 6.2 give the stored default values used by the PAN AIR system.

Note that when SDMS receives a value of zero (0) for the setname or user name for a database file it substitutes the setname value SYSTEM for the NOS/BE and SCOPE 2.1.3 systems and the user number value of the user's account card for the NOS/1.2 operating systems.

The user may want or be required to use his own values for the data base information parameters. It is to this end that the DATA BASE directives are available.

A few definitions are required before the DATA BASE directives are described.

The following abbreviations are used when discussing data base descriptions:

| | |
|---|---|
| dbnam | default data base name of from 1-6 characters |
| newmdn | new data base name of master definition of from 1-6 characters |
| newnam | replacement data base name of from 1-6 characters |
| pw | SDMS data base password of from 1-6 characters |
| un** | user number for data base |
| uid* | user identification for data base |

| | |
|---|---|
| set* | disk set name for data base |
| mun** | user number for master definition |
| muid* | user identification for master definition |
| mset | disk set name for master definition |
| dblist | a list of default data base names separated by blank or a comma |
| suffix | 1-3 character suffix to be added to data base name(s) |

* NASA Ames and Wright Patterson installations only

** Boeing EKS and Langley installations only

The DATA BASE directives are now described. The first and last must appear in that order while the other subordinate commands may be in any order.

DATA BASE DIRECTIVE BLOCK

This card is used to alert MEC that one or more data base information parameters are to be modified from their default values.

DBASE Card

DBASE dbnam = newnam [ PW = pw,+ ] [ UN = un,** ] [ UID = uid,* ] [ SET = set,* ] { { MDN = newmdn, } { MUN = mun** } { MUID = muid* } { MSET = mset } }

* CDC 7600 only ** CDC 6600 only

\+ Not used in current version

The keywords should be self explanatory when paired with the item they introduce (see definition of abbreviations).

APPEND Card

APPEND suffix TO dblist,ALL

This directive is used to change the name of one or more data bases by appending a 1-3 character suffix. The data base list may include permanent or temporary data bases.

The seven following directives all operate in the same fashion. They change data base parameters as indicated. The example given at the beginning

of section 6.0 illustrates changing DIP data base to DIPA1 by "APPEND", modifying the default values of "id" for MDG and CDP to FAELLE and using the user identifier PANAIR for all "id's" of the master definitions.

| | | |
|---|---|---|
| PW = pw | FOR | dblist, ALL+ |
| UN = un | FOR | dblist, ALL* |
| UID = uid | FOR | dblist, ALL** |
| SET = set | FOR | dblist, ALL** |
| MUN = mun | FOR | dblist, ALL* |
| MUID = muid | FOR | dblist, ALL** |
| MSET = mset | FOR | dblist, ALL** |

* Boeing and Langley Systems only (NOS 1.2 and NOS 1.3)
** Ames and Wright-Patterson Systems only (SCOPE 1.3 or NOS/BE)
\+ Not used in current version

RELEASE dblist, ALL

This directive is used to indicate that the data bases listed may be released (PURGED) as soon as the current PAN AIR run is finished using them. They will not be saved permanently. (Note that unless directed otherwise MEC automatically releases (purges) all databases.)

KEEP

KEEP FOR FUTURE { IC UPDATE | SOLUTION UPDATE | POST PROCESSING | FIELD FLOW | PRINT PLOT }

or

KEEP FOR FUTURE dblist, ALL

has two forms. The first is called a macro directive. MEC searches the "KEEP" directive for the macro keywords "IC", "SOLUTION," "POST," and "FIELD.* Each of those keywords tells MEC to save all data bases required to make a future run of the type specified. See table 6.3.

In the second form of the KEEP directive the initial keyword is followed by either "ALL" or a data base list. In this case MEC will purge all except these databases mentioned in the list.

END

The last data base directive must be END. This card is in addition to the END card required by the PAN AIR directive block.

### 6.2.3 Execution Directive Block

The execution directive block specifies the type of PAN AIR problem to be run. There are three standard types of problems and an almost endless number of non-standard problems. The standard runs consist of a full solution of a potential flow problem using no previous solution results, an IC update which assumes different geometry but with previous right-hand-side constraint data or a solution update which uses prior geometry and solution results with new right-hand-side constraint data. Any other run is called non-standard.

Before describing these directives in detail, a few definitions will be necessary.

The following abbreviations are used when describing execution directives.

| | |
|---|---|
| modnam | module name |
| unname | id/un associated with account number of files |
| db | data base name |
| lfn | local file name |
| vsn | volume set name for disk pack |
| sn | set name for a file |

The execution directives are now described.

EXECUTION DIRECTIVE BLOCK

This is the first card of the execution directive block.

This feature is especially useful for large problems since it allows a user to create the input for DIP (which might consist of thousands of cards) on a file and thus avoid the clumsiness accompanying such a large input deck. See appendix C.

INPUT lbn

If the user wants to specify a local file name "lfn" for input to the DIP module, the INPUT directive is needed. If it is not present, the default file "INPUT" is used.

FIND POTENTIAL FLOW, FIELD$^{+}$ FLOW, PLOT

results in the execution of the following PAN AIR modules: DIP, DQG, MAG, RMS, RHS, MDG, PDP, CDP. The modules PDP and CDP are not executed if data from them is not requested via DIP input data.

In addition, data bases required for future post processing (after MDG)

will be saved unless otherwise specified in the DATA BASE DIRECTIVE block. The ones saved are DIP and MDG.

The keyword "FIELD" would add the module OFB+ to the list (not available in version 1.0), and the keyword "PLOT" would cause the module PPP to be included at the end.

The directive

FIND IC UPDATE FIELD+ FLOW, PLOT

results in the execution of the same modules as the "POTENTIAL FLOW" macro. However, data bases from a previous run are required and the following modules work differently internally: DIP, MAG, RMS, RHS.

The directives

FIND SOLUTION UPDATE, FIELD+ FLOW, PLOT

results in the execution of the following modules: DIP, RHS, MDG, PDP, CDP and optionally OFB/PPP.

The next six directives are used to run non-standard PAN AIR runs. They are all optional and can be used in any order. They may also appear before and after the other standard directives. An example of a non-standard run is given in section 6.3.

The directive

RUN modnam SIC, un, sn

causes the file named 'modnam' to be executed. If "modnam" is not one of the standard PAN AIR modules, then the special word "SIC" must be added to the card to warn MEC. Otherwise, MEC will reject unrecognized modules and prematurely terminate execution.

The directive

DROP db SIC, un, sn

indicates that all data bases in the list are to be released when the current PAN AIR run is through with them. The keyword "SIC" allows a non-PAN AIR data base to be dropped (purged).

MOUNT DISMOUNT

The two directives

MOUNT vsn, sn

DISMOUNT vsn, sn

+ Not available in Version 1.0 of PAN AIR

are included to mount or dismount a removable disk pack. They must be used if the PAN AIR software system is on a removable disk pack. The command MOUNT must appear before the FIND directive.

CC =

The directive

CC = standard CDC control card

is placed directly into the stream of control cards generated by MEC. The module MEC strips off the "CC =" and writes the remainder to the control card file. The blank between "CC" and "=" is mandatory.

ERROR

The directive

ERROR Blank, U, C

can be inserted into the control card stream to allow exit conditions in case an error during execution occurs. This card results in EXIT, EXIT (U) or EXIT (C).

END

The last directive END must be included as the last directive of an EXECUTION DIRECTIVE block. Hence, if execution directives are specified, two END cards appear, one for the termination of the execution block and one for termination of the the PAN AIR directive block.

## 6.3 Guide to MEC Directive Construction

This section provides the user with guidance in the preparation of MEC directives. It is intended to provide an outline of basic directives with suggestions as to how a user might modify the outline to satisfy his/her unique requirements.

MEC directives must always begin with the "PAN AIR" card and end with an "END" card. Unless the user is running on a Boeing computer system, the "SYSTEM ..." directive must occur after the "PAN AIR" card. For practical reasons some number of database directives will always be required so the database directive block will also be a part of most MEC directives. Unless the user is familiar with the control card structure of his system and is extremely patient about punching many control cards, the execution directive block will also be a part of every set of MEC directives. Thus the basic MEC directive deck should look like table 6.4.

Only one command will be typically employed in the execution directives. (See the exception concerning post processing runs below). For the first run of a problem the user should specify FIND POTENTIAL FLOW. After this run has

been executed, a subsequent run might employ one of the directives FIND IC UPDATE or FIND SOLUTION UPDATE, but the first run must have been done with the FIND POTENTIAL FLOW directive (plus appropriate directives to save the required databases, as discussed below).

Table 6.9 illustrates the basic set of MEC directives which users will typically wish to employ to run the system.

The remainder of this section discusses some additional useful modifications and extensions to this basic set of directives.

Certain MEC directives are useful conveniences rather than necessary commands. These are the RID and the CHECK DATA directives. The RID allows the user to label the printed output with a phrase which briefly (76 characters) summarizes the run. The CHECK DATA directive will cause a limited set of control cards to be generated which will run DIP or DIP and DQG and then stop execution. This allows the user to verify that the problem to be solved has no input errors and is in fact the problem whose solution is desired. Thus a user might modify the set of directives in table 6.9 in the manner of table 6.10.

The database directives MDN, MUN, MUID and MSET are primarily useful for program development and will not generally be required by the user. They specify alternarive file names and/or identification for the master definition files used to generate the databases used in PAN AIR. (See the PAN AIR SYSTEM MAINTENANCE MANUAL, section 13.)

Some directives should be added to the basic deck if either an IC update or a solution update run is planned.

Figure 4.3-4 indicates that for an IC update run the DIP databases, the database generated by MAG (MAK) and the database generated by RMS must be saved after the first run in order to run an IC update. Figure 4.3-3 indicates that the MAK databases will be purged by the MEC control cards after the execution of MDG in the normal course of a potential flow solution unless MEC is otherwise directed. Adding the command "KEEP FOR FUTURE IC UPDATE" to the database directive block causes MEC to save the databases required for the update run instead of purging them at the end of MDG execution.

In a similar fashion a solution update run requires the same set of databases that an IC update run requires plus the DQG database. By adding the directive

"KEEP FOR FUTURE SOLUTION UPDATE"

to the database directive block the user will insure that the appropriate databases are available for the future run.

If additional post processing is anticipated the

"KEEP FOR FUTURE POST PROCESSING"

directive will insure the DIP and MDG databases are available for the post processing run(s).

The CC= directive allows a user to insert control cards into the sequence of control cards generated by MEC. One application of this directive is illustrated in table 6.11. Here a user compiles and executes a program which automatically generates the input deck required to define the geometry of his configuration in the form required by DIP. Thus the CC= directives first run the geometry program and then the FIND directives cause MEC to generate the sequence of control cards which will solve the problem. Note that the example also illustrates the INPUT directive. The user's program creates the DIP input data on a file called CONFIG. The INPUT directive causes module DIP to read file CONFIG to obtain the input data instead of the default file INPUT.

Another use of the CC= directive is shown in table 6.12. Here a user has found the last error in a PAN AIR module while trying to solve a potential flow problem. In order to help the maintenance staff find the difficulty, the user has inserted an appropriate set of cards to generate a core dump of the module in which the error has occurred. This sequence is generated by adding an ERROR(U) directive followed by the CC= directives which generate the core dump. Note that all database files have been saved by the KEEP FOR FUTURE ALL directive. This allows the PAN AIR maintenance staff to later examnine the contents of the databases if more information is required than is furnished in the core dump.

Two related directives which might be useful at the Ames and Wright-Patterson sites are the MOUNT and DISMOUNT directives. The PAN AIR modules and database master definitions are stored on a removable disk pack. This pack must be mounted in order to run PAN AIR. This normally would be accomplished with control cards provided by the user (see section 5.2). However the user might want the database files generated by PAN AIR to reside on another removable disk pack which belongs to him. In this case either the user must mount and dismount the required pack by using the MOUNT, DISMOUNT directives or he must be sure to mount the pack(s) by adding the appropriate cards to the user provided control cards discussed in section 5. Note that in the job card the user must specify the YD2, YLm parameters as in

```
DUALMT,Tnnn,CMXXXXXX,PN,YD2,YL7.
```

Table 6.13 illustrates the appropriate MEC directives. The user mounts his private pack and runs the PAN AIR system saveing all databases. Then he dismounts the PAN AIR disk pack and then attaches and executes a file of his own called SCANDB.

The MEC directives for an original run followed by those for one or more updates illustrates the use of most commands discussed so far. Table 6.14 illustrates the MEC directives for the original run in which an IC update, a solution update and additional post processing runs are anticipated. Table 6.15 and 6.16 illustrate the directives for the update runs and post processing runs. Note that in the IC update and solution update runs a new name is given for the MDG databases. This allows the uer to perform a number of additional post processing runs on the different MDG databases to obtain data which allows detailed comparisons among the variously modified configurations. Tables 6.17 and 6.18 illustrate the appropriate directives for two such post processing runs. Notice that these sets of directives employ the RUN directive to define the post processing execution sequence. Modules DIP, PDP and PPP are executed in this case. The extension to execution of CDP should be obvious.

## 6.4 Use of PAN AIR at Non-Standard Installations

PAN AIR has been designed to simplify the demands on the user with regard to control card construction. This simplification is effected only for the small number of operating systems and computer installations at which PAN AIR has been delivered. If a user wishes to run PAN AIR at other installations, the control cards generated by MEC may be erroneous or inadequate. If this is the case the user must provide all control cards by himself either by completely generating his own decks (using the MEC output as a guide) or by modifying the control cards generated by MEC so that they are compatible with his system.

The appropriate SYSTEM card to use in a non-standard installation will depend on whether the computer site allows removable disk packs or not. If these are available then either the AMES or WRIGHT locations should provide the most nearly correct set of control cards. If this is not available, then either the BOEING or LANGLEY specification should provide the best set of control cards.

The exact form of the "SYSTEM..." card will depend on which operating system the user is running under. The card determines what set of control cards MEC will create and specifies identification information necessary to access the MEC master definition file and all other master definition files for the database used in the PAN AIR system. Note that while other database file master definitions can be specified through the use of the database directive section, the SYSTEM card is the only way in which the identification information for the MEC master definition file can be specified. The appropriate card to use at each installation is shown in table 6.5. The exact file identification is subject to change, so check with local PAN AIR representatives for current values of file identification.

Most users will wish to add database directives to modify the names of the database files. The simplest directive which accomplishes the labeling is the APPEND directive, as in

```
APPEND XYZ TO ALL
```

This command defines names for all database files. The names are of the form DIPXYZ1, DIPXYZ2, DIPXYZ3, DIPXYZ4, DQGXYZ1, DQGXYZ2, etc. In addition the DBASE directive can be used to name database files. This is most useful when used in conjunction with an APPEND ... ALL to make some exceptions to the global operation invoked by the APPEND statement.

It will also be necessary for most users to specify some sort of user number or user identifier and setname under which the permanent database files will be catalogued. The appropriate directive to define this depends on the operating system. For Boeing and Langley the UN= directive is the appropriate one. For Ames and Wright-Patterson systems, both the SET= and the UID= cards will need to be supplied. Table 6.6 and 6.7 illustrate the use of the APPEND and DBASE commands. The results of using the directives in either example is identical. Table 6.8 illustrates a more sensible use of the DBASE command than that shown in Table 6.7. (Note that the order of the APPEND and DBASE directives affects the results. If the DBASE command preceeded the APPEND command, the MDG database files names would be MDGXYZn. Thus MEC processes the database directives in the same order as they occur in the input deck.)

| DEFAULT NAME | ACTUAL NAME | SET NAME* USER NO** | USER ID* ---- | PASWRD | MASTER DEF NAME | SET NAME*+ USER NO** | USER ID*+ ---- |
|---|---|---|---|---|---|---|---|
| DIP | DIP | 0 | 0 | 0 | DIPMD | 0 | 0 |
| DQG | DQG | 0 | 0 | 0 | DQGMD | 0 | 0 |
| MAK | MAK | 0 | 0 | 0 | MAKMD | 0 | 0 |
| RMS | RMS | 0 | 0 | 0 | RMSMD | 0 | 0 |
| RHS | RHS | 0 | 0 | 0 | RHSMD | 0 | 0 |
| MDG | MDG | 0 | 0 | 0 | MDGMD | 0 | 0 |
| PDP | PDP | 0 | 0 | 0 | PDPMD | 0 | 0 |
| CDP | CDP | 0 | 0 | 0 | CDPMD | 0 | 0 |

* CDC 7600 only ** CDC 6600 only

\+ These values are modified by the entries in the SYSTEM card.

Table 6.1 - PAN AIR permanent data base default descriptions

| DEFAULT NAME | ACTUAL NAME | SET NAME* USER NO** | USER ID* ---- | PASWRD | MASTER DEF. NAME | SET NAME*+ USER NO** | USER ID*+ ---- |
|---|---|---|---|---|---|---|---|
| MAGX | MAGX | 0 | 0 | 0 | MAGXMD | 0 | 0 |
| MAGY | MAGY | 0 | 0 | 0 | MAGYMD | 0 | 0 |
| MAGZ | MAGZ | 0 | 0 | 0 | MAGZMD | 0 | 0 |
| RMST | RMST | 0 | 0 | 0 | RMSTMD | 0 | 0 |
| RHSX | RHSX | 0 | 0 | 0 | RHSXMD | 0 | 0 |
| MDGF | MDGF | 0 | 0 | 0 | MDGFMD | 0 | 0 |
| MDGC | MDGC | 0 | 0 | 0 | MDGCMD | 0 | 0 |
| MDGM | MDGM | 0 | 0 | 0 | MDGMMD | 0 | 0 |
| PDPT | PDPT | 0 | 0 | 0 | PDPTMD | 0 | 0 |
| CDPT | CDPT | 0 | 0 | 0 | CDPTMD | 0 | 0 |

* CDC 7600 only ** CDC 6600 only

\+ These values are modified by the entries in the SYSTEM card.

Table 6.2 - PAN AIR temporary data base default descriptions

| FUTURE IC UPDATE | FUTURE SOLUTION UPDATE | FUTURE POST PROCESSING | FUTURE FIELD FLOW+ | FUTURE PRINT/PLOT |
|---|---|---|---|---|
| DIP | DIP | DIP | DIP | DIP |
| | DQG | | DQG | DQG |
| MAK | MAK | | MAK | PDP |
| RMS | RMS | | RMS,RHS | CDP |
| | | MDG | | |

* Not available in Version 1.0 of PAN AIR software

Table 6.3 Data bases required for future PAN AIR runs

```
PAN AIR
     SYSTEM ....
     DATABASE DIRECTIVE BLOCK
          ...
          ...
          ...
     END
     EXECUTION DIRECTIVE BLOCK
          ...
          ...
          ...
     END
END
```

Table 6.4 - Outline of basic set of MEC directives

| | |
|---|---|
| Boeing Computers: | SYSTEM PADJR1 BOEING |
| NASA/Langley Computer: | SYSTEM 039458C LANGLEY |
| NASA/Ames Computer: | SYSTEM PANAIR FAEBRP2 AMES |
| Wright-Patterson AFB Computer: | SYSTEM PANAIR AFFDL WRIGHT |

Table 6.5 - System cards at various installations

Boeing System (NOS 1.2)

```
PANAIR
     SYSTEM PADJR1 BOEING
     DATABASE DIRECTIVE BLOCK
          APPEND XYZ TO ALL
          UN = PADJR1 FOR ALL
     END
     EXECUTION DIRECTIVES
          ...
          ...
     END
END
```

Langley System (NOS 1.3)

```
PANAIR
     SYSTEM 039458C LANGLEY
     DATABASE DIRECTIVE BLOCK
          APPEND XYZ TO ALL
          UN = SSDDS3 FOR ALL
     END
     EXECUTION DIRECTIVES
          ...
          ...
     END
END
```

Ames System (NOS 1.2)
(NOS/BE)

```
PANAIR
     SYSTEM PANAIR FAEBRP2 AMES
     DATABASE DIRECTIVES
          APPEND XYZ TO ALL
          UID = ALL
          SET = FAEBRP2 ALL
     END
     EXECUTION DIRECTIVES
          ...
          ...
     END
END
```

Wright-Patterson System

```
PANAIR
     SYSTEM  PANAIR WRIGHT
     DATABASE DIRECTIVES
          APPEND XYZ TO ALL
          UID = JEB ALL
          SET = AFFDL ALL
     END
     EXECUTION DIRECTIVES
          ...
          ...
     END
END
```

Table 6.6 - Example of the use of the APPEND directive

Boeing System (NOS 1.2)

```
PANAIR
     SYSTEM PADJR1 BOEING
     DATABASE DIRECTIVES
          DBASE DIP=DIPXYZ, UN=PAJEB1
          DBASE DQG=DQGXYZ, UN=PAJEB1
          DBASE MAK=MAKXYZ, UN=PAJEB1
          DBASE MAU=MAUXYZ, UN=PAJEB1
          DBASE MIC=MICXYZ, UN=PAJEB1
          DBASE RMS=RMSXYZ, UN=PAJEB1
          DBASE RHS=RHSXYZ, UN=PAJEB1
          DBASE RMS=RMSXYZ, UN=PAJEB1
          DBASE MDG=MDGXYZ, UN=PAJEB1
          DBASE PDP=PDPXYZ, UN=PAJEB1
     END
     EXECUTION DIRECTIVES
          ...
          ...
     END
END
```

Ames System SCOPE (2.1.3)

```
PANAIR
     SYSTEM PANAIR FAEBRP2 AMES
     DATABASE DIRECTIVES
          DBASE DIP=DIPXYZ, SET=FAEBRP2, UID=JEB
          DBASE DQG=DQGXYZ, SET=FAEBRP2, UID=JEB
          DBASE MAK=MAKXYZ, SET=FAEBRP2, UID=JEB
          DBASE MAU=MAUXYZ, SET=FAEBRP2, UID=JEB
          DBASE MIC=MICXYZ, SET=FAEBRP2, UID=JEB
          DBASE RMS=RMSXYZ, SET=FAEBRP2, UID=JEB
          DBASE RHS=RHSXYZ, SET=FAEBRP2, UID=JEB
          DBASE RMS=RMSXYZ, SET=FAEBRP2, UID=JEB
          DBASE MDG=MDGXYZ, SET=FAEBRP2, UID=JEB
          DBASE PDP=PDPXYZ, SET=FAEBRP2, UID=JEB
     END
     EXECUTION DIRECTIVES
          ...
          ...
     END
END
```

Table 6.7 - Example of the DBASE directive

Boeing System (NOS 1.2)

```
PANAIR
     SYSTEM PADJR1 BOEING
     DATABASE DIRECTIVES
          APPEND XYZ TO ALL
          UN=PAJEB1 FOR ALL
          DBASE MDG=MINDAT
     END
     EXECUTION DIRECTIVES
          ...
          ...
     END
END
```

Table 6.8 - A more efficient use of the DBASE directive.

Ames System (SCOPE 2.1.3)

```
PANAIR
     SYSTEM PANAIR FAEBRP2 AMES
     DATABASE DIRECTIVES
          APPEND JEB TO ALL
          SET = FAEBRP2 FOR ALL
          UID = JEB FOR ALL
     END
     EXECUTION DIRECTIVES
          FIND POTENTIAL FLOW
     END
END
```

Boeing System (NOS 1.2)

```
PANAIR
     SYSTEM PADJR1 BOEING
     DATABASE DIRECTIVES
          APPEND JEB TO ALL
          UN = PAJEB1 FOR ALL
     END
     EXECUTION DIRECTIVES
          FIND POTENTIAL FLOW
     END
END
```

Table 6.9 - Basic set of MEC directives for Boeing and Ames systems

Boeing System (NOS 1.2)

```
PAN AIR
     SYSTEM PADJR1 BOEING
     RID BOEING SYSTEM MEC DIRECTIVES
     CHECK DATA
     DATABASE DIRECTIVES
          APPEND JEB TO ALL
          UN=PAJEB1 FOR ALL
     END
     EXECUTION DIRECTIVES
          FIND POTENTIAL FLOW
     END
END
```

Table 6.10 - Example of variation of basic set of MEC directives

```
PAN AIR
     SYSTEM PADJR1 BOEING
     RID TEST GEOMETRY GENERATOR
     DATABASE DIRECTIVES
          APPEND GG TO ALL
          UN=PAJEB1 FOR ALL
     END
     EXECUTION DIRECTIVES
          CC=FTN,I,L,OPT=2.
          CC=LDSET(PRESET=INDEF).
          CC=LGO(INPUT,OUTPUT,CONFIG).
          CC=REWIND,CONFIG.
          INPUT = CONFIG
          FIND POTENTIAL FLOW SOLUTION.
     END
END
```

Table 6.11 - Example of the use of the CC= directive

```
PAN AIR
     SYSTEM PADJR1 BOEING
     RID TEST GEOMETRY GENERATOR
     DATABASE DIRECTIVES
          APPEND BUG TO ALL
          UN=PAJEB1 FOR ALL
          KEEP FOR FUTURE ALL
     END
     EXECUTION DIRECTIVES
          FIND POTENTIAL FLOW SOLUTION.
          ERROR U
          CC=DMP,1,20000
          CC=DMP,32577,47650
     END
END
```

Table 6.12 - Example of CC= directives to help debug a module.

```
PAN AIR
     SYSTEM  PANAIR FAEBRP2 AMES
     RID DATABASE FILES ON PRIVATE PACK
     DATABASE DIRECTIVES
          APPEND MIN TO ALL
          SET = FAEBRP3 FOR ALL
          UID = JEB FOR ALL
          KEEP FOR FUTURE ALL
     END
     EXECUTION DIRECTIVES
          MOUNT D0267A FAEBRP3
          FIND POTENTIAL FLOW
          DISMOUNT D0183A FAEBRP2
          CC=ATTACH(SCANDB,ID=JEB,SN=FAEBRP3)
          CC=SCANDB
     END
END
```

Table 6.13 - Example of MOUNT and DISMOUNT directives

```
PAN AIR
     SYSTEM PANAIR FAEBR2 AMES
     RID ORIGINAL RUN OF CASE FOR MODIFICATION
     CHECK DATA
     DATABASE DIRECTIVES
          APPEND ORG TO ALL
          SET = FAEBRP2 FOR ALL
          UID = JEB FOR ALL
          KEEP FOR FUTURE IC UPDATE
          KEEP FOR FUTURE POST PROCESSING
          KEEP FOR FUTURE PDP
     END
     EXECUTION DIRECTIVES
          FIND POTENTIAL FLOW
     END
END
```

Table 6.14 - MEC directives for original run

```
PAN AIR
     SYSTEM PANAIR FAEBRP2 AMES
     RID IC UPDATE OF ORIGINAL RUN
     DATABASE DIRECTIVES
          APPEND ORG TO ALL
          SET = FAEBRP2 FOR ALL
          UID = JEB FOR ALL
          DBASE MDG = MDGICU
          DBASE PDP = PDPICU
          KEEP FOR FUTURE SOLUTION UPDATE
          KEEP FOR FUTURE POST PROCESSING
          KEEP FOR FUTURE PDP
     END
     EXECUTION DIRECTIVES
          FIND IC UPDATE
     END
END
```

Table 6.15 - MEC directives for subsequent IC update.

```
PAN AIR
     SYSTEM PANAIR FAEBR2 AMES
     RID SOLUTION UPDATE OF IC UPDATE
     DATABASE DIRECTIVES
          APPEND ORG TO ALL
          SET = FAEBRP2 FOR ALL
          UID = JEB FOR ALL
          DBASE MDG = MDGSUP
          DBASE PDP = PDPSUP
          KEEP FOR FUTURE POST PROCESSING
          KEEP FOR FUTURE PDP
     END
     EXECUTION DIRECTIVES
          FIND SOLUTION UPDATE
     END
END
```

Table 6.16 - MEC directives for solution update of IC update run.

```
PAN AIR
     SYSTEM PANAIR FAEBRP2 AMES
     RID SOLUTION UPDATE OF IC UPDATE
     DATABASE DIRECTIVES
          APPEND ORG TO ALL
          SET = FAEBRP2 FOR ALL
          UID = JEB FOR ALL
          DBASE PDP = PDPPPO
     END
     EXECUTION DIRECTIVES
          RUN DIP PANAIR FAEBRP2
          RUN PDP PANAIR FAEBRP2
          RUN PPP PANAIR FAEBRP2
     END
END
```

Table 6.17 - MEC directives for post processing runs post processing for original run.

```
PAN AIR
     SYSTEM PANAIR FAEBRP2 AMES
     RID SOLUTION UPDATE OF IC UPDATE
     DATABASE DIRECTIVES
          APPEND ORG TO ALL
          SET = FAEBRP2 FOR ALL
          UID = JEB FOR ALL
          DBASE PDP = PDPPRI
          DBASE MDG = MDGICU
     END
     EXECUTION DIRECTIVES
          RUN DIP PANAIR FAEBRP2
          RUN PDP PANAIR FAEBRP2
          RUN PPP PANAIR FAEBRP2
     END
END
```

Table 6.18 - MEC directives for post processing run:
post processing for IC update run.

# 7.0 DIP Input Records

The input records read by the DIP module specify the flow problem to be solved by PAN AIR. The DIP input records are described in this section. General rules are given for the formats and organization of the input records. The input records then are described for each data group.

The input records read by the DIP module are organized and written onto a data base for use by the subsequent program modules. The calculations in the DIP module are restricted to a few data adjustments and some checks on the validity of the input data. The optional printout of the DIP module allows the user to inspect the input data, some intermediate calculations, and the options selected by the program.

## 7.1 General Rules

The general rules for preparation of the DIP input records are listed in this section: first, those for defining the physical model and, second, those for preparing input records.

### 7.1.1 Physical Model

All configuration data must be specified in a reference coordinate system (see appendix B.2.1). This system must be orthogonal and right-handed, but is otherwise arbitrary. PAN AIR has an implied reference coordinate system: $x_0$ positive aft, $y_0$ positive right, and $z_0$ positive up. The program defaults are based upon the implied reference coordinate system.

The dimensional unit of all length quantities is established by the reference coordinate system. This dimensional unit must be used for all specified geometry (network grid point and other point coordinates), for other geometric quantities (tolerance distances, length and area reference parameters), and all velocity quantities (uniform onset velocity, local onset flow velocity, specified flows, and so forth).

The dimensional unit of all time quantities is established by the user-specification of uniform onset velocity (record G6). This dimensional unit must be used for all other time-related quantities: rotational onset flow velocity, local onset flow velocity and specified flows in the boundary condition equations. In many applications the user will give the uniform onset velocity a unit value. This scales the time dimensional unit; all other time-related quantities (the velocity quantities listed above) must be scaled in the same manner.

### 7.1.2 Input Records

#### 7.1.2.1 Structure of Input Records

The symbology used for the input records is listed in table 7.1. Input records are of three basic types. First, an instruction record consists only of a primary keyword ("ITEM", table 7.1) which identifies the instruction being specified. Second, an instruction-parameter record consists of a primary keyword, followed by an equal sign, followed by one or more secondary keywords ("Item", table 7.1) to specify particular options, or by a user-supplied name ("item", table 7.1), or by numerical data, or by a combination of the three. Third, a data record consists of numerical data only.

---

**<>** -- Data items enclosed in brackets have default values.

{ } -- Data items enclosed in braces have optional input entries. One of the indicated options must be selected.

{{ }} -- Data items enclosed in double braces have optional input entries. One or more of the indicated options must be selected.

Note: Brackets **< >** , braces { } , and double braces {{ }} used in describing the record formats are not input.

ITEM -- An item typed in all upper case letters is a primary keyword. At least the underlined portion(s) must be input. If portions of two words are underlined, they must be separated by at least one blank.

Item -- An item with only the leading character typed in upper case must be selected from a list of secondary keywords. If several secondary keywords are input, their ordering is arbitrary. At least the underlined portion of keywords must be input. Imbedded blanks are not allowed in secondary keywords.

item -- An item typed in all lower case letters is defined by the user.

Note: All data on a record starting with a primary keyword (ITEM) must be on a single record unless "record continuation" is indicated by a plus (+) as the last character on a card.

Table 7.1 Symbology for input records

---

#### 7.1.2.2 Defaults

A default is the instruction, option, or numerical data assigned by the DIP module when the user omits part or all of an input record. There are two types of defaults. First, a record default is the omission of the entire input record. Second, a parameter default occurs in an instruction-parameter

record when some or all of the parameters are omitted. Both types of defaults are identified in the descriptions of the input records (sections 7.3 to 7.7).

#### 7.1.2.3 Format Rules

The user-specified input records must satisfy the format rules listed below:

1. Two delimiters (which are interchangeable) are used to separate words and numbers: blank and comma. An equal sign (=) is used as a special delimiter to separate primary keywords from subsequent data and to separate user-specified names from secondary keywords.

2. Numerical values are read in free-field format only; individual values must be separated by delimiters. Integers and floating point numbers must be properly input, for example, integers are not converted to floating point numbers by the program. A special format is used for repeated values. For example, three consecutive 1.5 values can be input as "1.5, * = 2" which is interpreted: a single 1.5 value and that value repeated 2 more times.

3. User-defined alphanumeric names can consist of 1 to 20 characters. Input alphanumeric names with more than 20 characters are truncated to the first 20 characters. Alphanumeric names can consist of letters, integers, and the symbols hyphen, period and both parentheses. Imbedded blanks are not allowed. The alphanumeric names are arbitrary except they cannot be purely numerical or something that will be interpreted as numerical. For example, "E5" will be interpreted as "1.E+5" by the program.

4. Record continuation is indicated by a plus (+) as the last character on a card. The continuation symbol must not split a word or a number.

5. Record continuation is not required for data records, that is, records which give numerical values only. A series of numerical values can be arbitrarily separated onto different cards. There is one exception: for numerical values which occur in triplets (that is, coordinates or vector components), each triplet must be on a single card. If a triplet is split onto more than one card, then record continuation is required.

6. Input records do not require a terminator. The optional record terminator is a slash (/) which can be used to add comments: the DIP module ignores the text following the slash. Record continuation (rule 4 above) cannot be used with comments. An input card starting with a star-slash (*/) or a slash (/) is ignored by the program and can be used for comments.

7. Several records can be combined onto a single card if they are separated by a dollar sign ($).

7.1.2.4 Records and Cards

In most cases one input record is one computer card. However, one input record can consist of several cards under the record continuation feature, rules 4 and 5 in the list above. Several input records can be placed on a single computer card, rule 7 in the list above. Also, the DIP module will accept either physical cards or card images.

7.1.2.5 Examples

Several sample applications follow, illustrating the symbology and the formats used in description of the input records in sections 7.3 to 7.7. In each case the symbolic description of the input record is given, followed by an example of the record. Each example is given in two or more formats which give identical instructions and data to the program, thus illustrating alternate formats which can be used for the input records.

1. Primary keyword only

Input data listing:

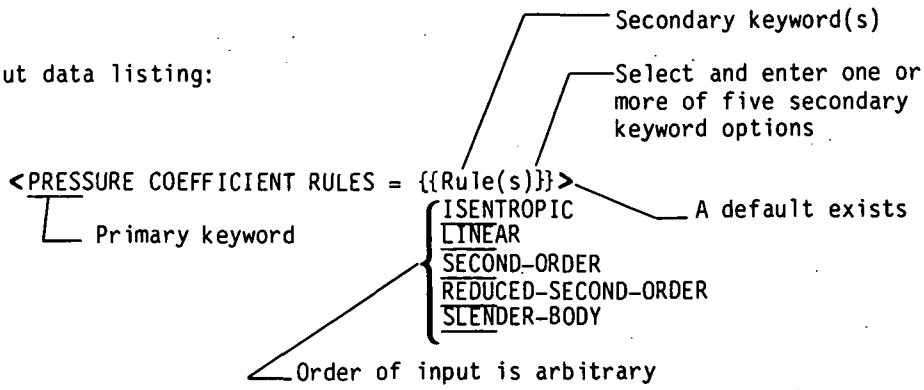
BEGIN NETWORK DATA

Example:

```
BEGIN NETWORK DATA
BEGI NETW
```

2. Primary and secondary keywords

Input data listing:




Example:

```
PRESSURE COEFFICIENT RULES = ISENTROPIC, SECOND-ORDER
PRES = ISEN, SECO
PRES = SECO, ISENTROPIC /COMMENT WITH ANY USER-SUPPLIED TEXT
```

3. Primary keyword and data

Input data listing:
<SOLUTIONS = {{solution-id(I)}}>

Example:
SOLUTIONS = 1,3,6
SOLU=1 3 6

4. Primary keyword and data with default values

Input data listing:
<RATIO OF SPECIFIC HEATS = {{gamma(s)}}>

Record Default: gamma = 1.4 for all values in the array
(that is, gamma = 1.4, 1.4, 1.4, 1.4, 1.4, ...)

Example:
RATIO OF SPECIFIC HEATS = 1.667, 1.4, 1.286
RATI = 1.667, 1.4, 1.286

Resulting array: gamma = 1.667, 1.4, 1.286, 1.4, 1.4, ...

5. Primary and secondary keywords and data

Input listing:
<ABUTMENT {{ = network-id, edge-number <end-point pair / ENTIRE-EDGE>}}>

Example:
ABUTMENT = WING-A, 3, ENTIRE-EDGE +
= WING-B, 1, 1, 4 +
= WING-C, 3
} One input record

ABUT = WING-A, 3, ENTI = WING-B, 1, 1, 4 = WING-C, 3

The equal signs are used to separate the user-supplied network-id names.

### 7.1.2.6 Input Records with a List of User-Specified Names

The user can specify alphanumeric names for solutions, networks and two types of calculation cases (surface flow properties, and forces and moments). These names are arbitrary except for the restrictions under rule 3 of section 7.1.2.3 and for a requirement that the names in each category to be distinct. Also an integer index, which corresponds to an (independent) alphanumeric name, is assigned by the DIP module. Subsequent references to the solutions, networks and the two types of calculation cases can use either the alphanumeric names (example 5 in the previous section) or the integer indices (example 3 in the previous section).

The requirements for the user-specified alphanumeric names to be arbitrary and for the alternative use of the corresponding integer indices has affected the design of the input records. There are two basic types of records if a list of alphanumeric names or integer indices is specified. The first type of record is a list of names/indices without any other instructions being specified. See example 3 of the previous section. The record has (in addition to the primary keyword) a single equal sign followed by the list of names/indices, which must be separated by at least one delimiter (blank or comma). The second type of record is a list which includes the names/integers along with other instructions. See example 5 of the previous section. In this type of record each of the names/indices is preceded by an equal sign. The DIP module uses the equal signs to distinguish the names/indices from the other instructions on the record.

### 7.1.2.7 Program Limitations

PAN AIR has the following limitations.

```
Number of solutions:  200
Number of networks:   100
Number of calculation cases -
     Surface flow properties:  100
     Forces and moments:  100
```

The DIP module enforces these limitations. The limitations on the solutions and on both calculation cases can be avoided by using the update capabilities, see section 7.2.3. Note that there is no direct limitation on the number of panels, but this number strongly influences the cost of a computer run.

## 7.2 Input Record Listing

The set of DIP input records is described briefly in this section. Included are a description of the data groups and a listing of the input record names. Also included is a brief description of the PAN AIR update capability and the associated restrictions on the DIP input records.

### 7.2.1 Data Groups

The input records are divided into five data groups, which must appear in the order given below.

1. Global Data Group
   This data group serves two purposes. First, it defines basic program conditions which are required in the formulation of the flow problem. Second, it defines global default values for several quantities which appear in subsequent data groups.

2. Network Data Group
   This data group defines the basic configuration data, such as panel grid point geometry and boundary conditions, on an individual network basis.

3. Geometric Edge Matching Data Group
   This data group defines network abutments and associated boundary conditions, which usually involve more than one network.

4. Flow Properties Data Group
   This data group defines options for two types of post-solution calculations. Included in the group are instructions for calculation of surface flow properties (PDP module), and forces and moments (CDP module).

5. Print-Plot Data Group
   This data group defines various options for preparing files for subsequent printing and plotting of parts of the program output.

### 7.2.2 List of Input Records

The DIP input records are listed below. The records are organized by data groups. Each record has an identifying number. An asterisk (*) indicates that the record has ordering restrictions. Records G8 to G16 define global default options; these records are repeated (indicated by +) in later data groups so that the global options can be redefined locally.

Global Data Group

*G1. Global Data Group Identifier
G2. Problem Identification
G3. User Identification
G4. Configuration and Flow Symmetry
G5. Compressibility Data
G6. Global Onset Flow Record Set
G7. Tolerance for Geometric Edge Matching
G8. Surface Selection Options
G9. Selection of Velocity Computation Method
G10. Computation Option for Pressures
G11. Velocity Correction Options
G12. Pressure Coefficient Rules
G13. Ratio of Specific Heats
G14. Reference Velocity for Pressure
G15. Store Velocity Influence Coefficient Matrix
G16. Store Local Onset Flow
G17. Checkout Print Options

Network Data Group

*N1. Network Data Group Identifier
*N2. Network Identifier Record Set
    *N2a. Network Identifier
    *N2b. Grid Point Coordinates
N3. +(G15). Store Velocity Influence Coefficient Matrix
N4. +(G16). Store Local Onset Flow
N5. Reflection in Plane of Symmetry Tag
N6. Wake Flow Properties Tag
N7. Triangular Panel Tolerance
N8. Network and Edge Update Tag
N9. Boundary Condition Specification
N10. Method of Velocity Computation
N11. Singularity Types
N12. Edge Control Point Locations
N13. Remove Doublet Edge Matching
N14. Closure Edge Boundary Condition Record Set
    *N14a. Closure Edge Condition Identifier and Locator
    *N14b. Closure Term
    *N14c. Closure Solutions List
    *N14d. Closure Numerical Values

N15. Coefficients of General Boundary Condition Equation Record Set
*N15a. Coefficients of General Boundary Condition Equation Identifier
*N15b. Equation Term
*N15c. Equation Solutions List
*N15d. Equation Control Point Locations
*N15e. Equation Numerical Values
N16. Tangent Vectors for Design Record Set
*N16a. Tangent Vectors for Design Identifier
*N16b. Tangent Vectors Term
*N16c. Tangent Vectors Scaling
*N16d. Tangent Vectors Solutions List
*N16e. Tangent Vectors Control Point Locations
*N16f. Tangent Vectors Numerical Values
*N16g. Tangent Vectors Standard Numerical Values
N17. Specified Flow Record Set
*N17a. Specified Flow Identifier
*N17b. Specified Flow Term
*N17c. Specified Flow Symmetries
*N17d. Specified Flow Solutions List
*N17e. Specified Flow Control Point Locations
*N17f. Specified Flow Numerical Values
N18. Local Onset Flow Record Set
*N18a. Local Onset Flow Identifier
*N18b. Local Onset Flow Term
*N18c. Local Onset Flow Symmetries
*N18d. Local Onset Flow Solutions List
*N18e. Local Onset Flow Control Point Locations
*N18f. Local Onset Flow Numerical Values

Geometric Edge Matching Data Group
*GE1. Geometric Edge Matching Data Group Identifier
*GE2. Abutment Definition
GE3. Abutment in Planes of Symmetry
GE4. Smooth Edge Treatment Option

Flow Properties Data Group
*FP1. Flow Properties Data Group Identifier

Surface Flow Properties Data Subgroup
*SF1. Surface Flow Properties Subgroup Identifier
SF2. Networks and Images Selection
SF3. Solutions List
SF4. Calculation Point Locations Record Set
*SF4a. Point Types
*SF4b. Arbitrary Points
SF5. +(G8). Surface Selection Options
SF6. +(G9). Selection of Velocity Computation Method
SF7. +(G10). Computation Option for Pressures
SF8. +(G13). Ratio of Specific Heats

```
SF9.    +(G14).  Reference Velocity for Pressure
SF10.   Printout Options Record Set
   *SF10a.   Printout Options
   *SF10b.   +(G11).   Velocity Correction Options
   *SF10c.   +(G12).   Pressure Coefficient Rules
SF11.   Data Base Options Record Set
   *SF11a.   Data Base Options
   *SF11b.   +(G11).   Velocity Correction Options
   *SF11c.   +(G12).   Pressure Coefficient Rules
```

Forces and Moments Data Subgroup

```
*FM1.    Forces and Moments Subgroup Identifier
 FM2.    Reference Parameters
 FM3.    Axis Systems
 FM4.    Solutions List
 FM5.    Printout Options
 FM6.    Data Base Options
*FM7.    Case Identifier
 FM8.    Networks and Images Selection
 FM9.    Edge Force Calculation
 FM10.   Moment Axis
 FM11.   Local Reference Parameters
 FM12.   +(G8).    Surface Selection Option
 FM13.   +(G9).    Selection of Velocity Computation Method
 FM14.   +(G10).   Computation Option for Pressures
 FM15.   +(G11).   Velocity Correction Options
 FM16.   +(G12).   Pressure Coefficient Rules
 FM17.   +(G13).   Ratio of Specific Heats
 FM18.   +(G14).   Reference Velocity for Pressure
 FM19.   Local Printout Options
 FM20.   Local Data Base Options
 FM21.   Accumulation Options
```

Print-Plot Data Group

```
*PP1.    Print-Plot Data Group Identifier
 PP2.    Geometry Data Record Set
    *PP2a.    Geometry Data Identifier
    *PP2b.    Network Selection
 PP3.    Point Data Record Set
    *PP3a.    Point Data Identifier
    *PP3b.    Case Selection
    *PP3c.    Solutions List
    *PP3d.    Networks and Images Selection
    *PP3e.    Array Type
 PP4.    Configuration Data Record Set
    *PP4a.    Configuration Data Identifier
    *PP4b.    Case Selection
    *PP4c.    Solutions List
    *PP4d.    Networks and Images Selection
```

A termination record "END PROBLEM DEFINITION" can be used to indicate the end of the data. Its use is not required.

Within each group most input records can appear in any order. The exceptions are listed below by data groups. The repetitions which are possible within each group are identified.

Global Data Group: Record G1 (Global Data Group Identifier) must be the first record in the data group.

Network Data Group: Record N1 (Network Data Group Identifier) must be the first record in the data group. Records N2 to N18 are repeated for each network; record set N2 (Network Identifier Record Set) must be the first record(s) for each network. The other records can appear in any order. This includes the record sets N14 to N18; however the records within these record sets must be in the specified order since repetitions are allowed. The data for each network are independent, except for a global network option which can be defined in record N9.

Geometric Edge Matching Data Group: Record GE1 (Geometric Edge Matching Data Group Identifier) must be the first record in the data group. Records GE2 to GE4 are repeated for each abutment; record GE2 (Abutment Definition) must be the first record for each abutment. The data for each abutment are independent.

Flow Properties Data Group: Record FP1 (Flow Properties Data Group Identifier) must be the first record in the data group. The subsequent two data subgroups can appear in either order, but the data for one subgroup must be completed before starting the other subgroup. The Surface Flow Properties Data Subgroup allows repetition of all records to specify independent cases; record SF1 must be the first record for each case. The Forces and Moments Data Subgroup has two parts. Records FM1 to FM6 specify global options; record FM1 must be the first record in the data subgroup. Records FM7 to FM21 can be repeated to specify independent cases; record FM7 must be the first record for each case.

Print-Plot Data Group: Record PP1 (Print-Plot Data Group Identifier) must be the first record in the data group. The subsequent three record sets can appear in any order, but only once each. The records within the record set must be in the specified order.

### 7.2.3 Update Capabilities

The PAN AIR update capabilities allow the reuse of results from previous computer runs. These capabilities have cost advantages, since they save recomputation of results available in previous runs. Three types of update runs are available. The type is specified in the MEC language (see section 6). The distinction between the three types is based upon the results available from the previous run. The types of update runs are listed below in order of progression through a complete analysis. Each update includes the capabilities of those updates appearing below it in this list.

1. IC UPDATE (IC=influence coefficient): This is a left-hand side update requiring recomputation of partitions of the aerodynamic influence coefficient matrix, due to changes either in the surface geometry or in the left-hand side of any boundary condition equation.

2. SOLUTION UPDATE: This is a right-hand side update, which allows the introduction of new solutions or changes in existing solutions, including changes in the right-hand side of any boundary condition equation. For example, each solution allows different values of the onset flow, including the uniform onset flow speed and the angles of attack and sideslip, seeappendix B.2.2. The aerodynamic influence coefficient matrix and the left-hand sides of boundary condition equations cannot be changed.

3. POST PROCESSING UPDATE: This is a post-solution update: the solution for the singularity parameters can not be changed. This update allows the specification of flow properties calculations: surface flow properties, and forces and moments calculations can be specified. Also, the preparation of print-plot files can be specified.

In using the IC update, the associated network updating capability requires special consideration. An IC update allows modification of the configuration, including the replacement or deletion of existing networks, and the addition of new networks. However any network which is replaced or deleted must have been designated as "updateable" (record N8) in the originating run. All network edges which abut any updated network must also have been designated as updateable. (As a user convenience, the DQG module printout identifies any network edge which abuts an updateable network.) Otherwise, the IC update capability cannot be used; the modified configuration must be handled as a new run. Also, a program restriction requires that the entire configuration cannot be designated as updateable.

The SOLUTION update includes two options. These allow either the specification of a new set of solutions or the selective updating of the existing solutions defined in the originating run.

The POST PROCESSING update is post-solution, that is, the solution for the singularity distributions has been completed. The update allows specification of input data for post-solution calculation cases under two options. These allow either the elimination of all existing post-solution calculation cases or the selected updating of existing cases together with the addition of new cases.

The description of the input records, given in sections 7.3 through 7.7, includes all possible input records. For update runs the allowable set input records is restricted, since several quantities defined in the originating run (or in prior update runs) cannot be be redefined. A list of the allowable input records for each type of update run is given in table 7.2.

IC UPDATE
- Global Data Group: G1, G6, G8-G14, G17
- Network Data Group: all records for selected networks
- Geometric Edge Matching Data Group: all records for selected networks
- Flow Properties Data Group: all records
- Print-Plot Data Group: all records

SOLUTION UPDATE
- Global Data Group: G1, G6, G8-G14, G17
- Network Data Group: N1, N2a, N14-16 (only right-hand side data), N17, N18
- Geometric Edge Matching Data Group: none
- Flow Properties Data Group: all records
- Print-Plot Data Group: all records

POST PROCESSING UPDATE
- Global Data Group: G1, G8-G14, G17
- Network Data Group: none
- Geometric Edge Matching Data Group: none
- Flow Properties Data Group: FP1, SF1-SF11, FM1-FM21
- Print-Plot Data Group: all records

Table 7.2 - Allowable input records for each type of update run

## 7.3 Global Data Group

The global data group specifies basic program data and options. Records G2 to G7 and record G17 specify data and options which do not change during a run. Records G8 to G16 specify global defaults for data and options which appear in subsequent data groups. The Global Data Group must be present in an originating computer run, in an IC update and in a SOLUTION update.

Ordering: The first record in the Global Data Group must be the group identifier, record G1. The other records can appear in any order.

Record G1. Global Data Group Identifier

This record identifies the data group and specifies a possible solution update option. (The update option is specified in the MEC language as described in section 6; the update options are described in section 7.2.3.)

```
< BEGIN GLOBAL DATA = <Solution-update-option>>
                      NEW
                      REPLACE
                      UPDATE
```

Parameter Default: NEW

NEW: The computer run is either an originating run or a post-solution update (not a SOLUTION update nor an IC update).
REPLACE: All solution data (right-hand side data) from the previous run are eliminated. New solution data are specified in the Global and Network Data Groups; undefined solution data are given the listed default values.
UPDATE: The existing solution data are retained, but can be can be selectively updated, except that the number of solutions and the solution-id's cannot be changed. (Use this option if the solution data is not to be changed.)

Record Default: The global data group can be omitted in update runs. If omitted, the global defaults are those of the existing DIP data base. If this record is omitted, then omit all records in the data group.

Examples:

```
BEGIN GLOBAL DATA
BEGI GLOB = REPL
```

Records G2 and G3 are identifiers which will appear in the output. Each record is a single card. The identification names will consist of the last 76 characters on the card. These names have no restrictions on the use of symbols or imbedded blanks. (Note that records G2 and G3 are distinct from the Run ID and the User ID specified in the MEC data.)

Record G2. Problem Identification

<PID = problem identification>

Record Default: PID=NO PROBLEM ID

Record G3. User Identification

<UID = user identification>

Record Default: UID=NO USER ID

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Record G4. Configuration and Flow Symmetry

This record specifies possible planes of symmetry (see section B.2.3). The presence of configuration symmetry will reduce the amount of input data, since only the unique portion of the configuration is defined. The designated configuration symmetry must be complete, including all physical and wake surfaces. If the configuration is symmetric, the flow may be either symmetric or asymmetric. The user must be careful in the specification of the onset flow (record G6 and record set N18) and any specified flow (record set N17), which must be consistent with any flow symmetry specified here. The option of asymmetric flow should be used if there is any doubt about the flow symmetry.

<CONFIGURATION = List(n)>
List(n) options: If no planes of configuration symmetry, use List(1)
If one plane of configuration symmetry, use List(2)
If two planes of configuration symmetry, use List(3)

List(1) = ASYMMETRIC-GEOMETRY

List(2) = FIRST-PLANE <direction-numbers <point>><Flow-type>
ASYMMETRIC-FLOW
SYMMETRIC-FLOW
GROUND-EFFECT

List(2) parameter defaults make the $x_0z_0$ plane that of symmetry:
direction-numbers = 0., 1., 0.
point = 0., 0., 0.
Flow-type = SYMMETRIC-FLOW

List(3) = <List(2)> SECOND-PLANE<direction-numbers> <Flow-type>
ASYMMETRIC-FLOW
SYMMETRIC-FLOW
GROUND-EFFECT

List(3) parameter defaults make the $x_0z_0$ and $x_0y_0$ planes those of symmetry:
List(2) parameter defaults and
direction-numbers = 0., 0., 1.
Flow-type = SYMMETRIC-FLOW

The planes of symmetry are specified by the direction numbers (in the reference coordinate system) and by one point in the plane. The input direction numbers are normalized by the program to give the direction cosines, which are the components of the normal vectors $\hat{n}_1$ and $\hat{n}_2$. The positive direction(s) of the normal vector(s) must satisfy two rules:

(1) If there are networks in the plane of symmetry (record N5) then the normal vector must point from "point" in List(2) toward the input configuration.
(2) If there are two planes of symmetry then the compressibility vector $\hat{c}_0$ (record G5) must satisfy the relation $\hat{c}_0 = \hat{n}_1 \times \hat{n}_2$ . The GROUND-EFFECT

instruction is the same as the SYMMETRIC-FLOW instruction except that the forces and moments are computed on one-half (or one-quarter) of the total configuration. With List(2), if only three numbers are given for the "direction-numbers point" they are taken to be the direction numbers.

Record Default: CONFIGURATION = FIRST-PLANE, 0. 1. 0., 0. 0. 0., SYMMETRIC-FLOW
(That is, one plane of configuration symmetry, with the normal vector being the $y_0$-axis, and with symmetric flow.)

Restrictions: The direction numbers cannot be all zero, which is an error. With two planes of symmetry, the planes must be orthogonal: if the normals are not perpendicular within 0.01 degree, the program gives an error.

Examples:

CONFIGURATION = ASYMMETRIC-GEOMETRY
(That is, the configuration is asymmetric.)

CONF = FIRS, 0., 0., 1., SYMMETRIC-FLOW
(That is, one plane of configuration symmetry with normal vector being the $z_0$-axis, and with symmetric flow.)

CONF = FIRS, 0., 1., 0., 0., 0., 0., ASYM, SECO, 0., 0., 1., ASYM
(That is, two planes of configuration symmetry, with the normal vectors being the $y_0$-axis and the $z_0$-axis, respectively, and with asymmetric flow for both planes.)

Record G5. Compressibility Data

This record specifies the freestream Mach number and the compressibility direction, which is the x-axis of the Prandtl-Glauert equation, see sections A.1 and B.2.1. For incompressible flow (MACH = 0.), the compressibility direction is not required in theory, but one must be specified to avoid numerical problems. The compressibility angles of attack and sideslip, $\alpha_c$ and $\beta_c$, define the transformation between the reference coordinate system and the compressibility direction, $\hat{c}_0$, as shown in figure 7.1.

<MACH = mach> <CALPHA = calpha> <CBETA = cbeta>

mach = freestream Mach number; default = 0.
calpha = angle of attack defining the compressibility direction (degrees); default depends on configuration symmetry.
cbeta = angle of sideslip defining the compressibility direction (degrees); default depends on configuration symmetry.

The three instructions can be in any order on one, two or three records.

Restrictions and Defaults: If there are plane(s) of configuration symmetry (record G4), the compressibility direction must lie in those plane(s):

(1) In the case of one plane of symmetry and either zero Mach number or defaulted values of both calpha and cbeta , the program will define the compressibility direction as the projection of the $x_0$-axis (reference coordinate system) into the plane of symmetry.

(2) If at least one of calpha and cbeta is not defaulted, the compressibility direction must be in the plane of symmetry: if $\hat{c}_0$ and $\hat{n}_1$ are not perpendicular within 0.01 degree, the program gives an error.

(3) In the case of two planes of symmetry, the input values of calpha and cbeta are ignored; the compressibility direction will be the intersection of the two planes of symmetry, specifically $\hat{c}_0 = \hat{n}_1 \times \hat{n}_2$. The resulting compressibility direction must be approximately in (that is, not opposing) the flow direction.

Example:
MACH = .7 CALPHA = 2. CBETA = 3.

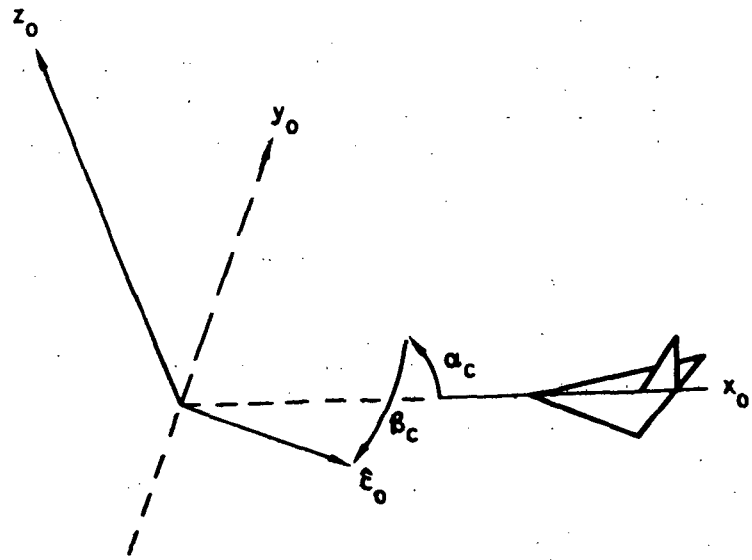



Figure 7.1 - Definition of the compressibility vector $\hat{c}_o$ in terms of $\alpha_c$ and $\beta_c$ and the reference coordinate system ($x_o$, $y_o$, $z_o$)

Record Set G6. Global Onset Flow Record Set

This record set specifies the global onset flow and the basic solution data, that is, the data defining the right-hand side of the boundary condition equations. Some additional solution data may be defined for individual networks: specified flow (record set N17) and local onset flow (record set N18) terms. The global onset flow consists of a uniform and a rotational flow, which are described in figure 7.2. Note that a rotation of the flow field, not a rotation of the vehicle, is specified. The direction of the uniform onset flow velocity $\underset{\sim}{U}_\infty$ is defined by the angles $\alpha$ and $\beta$, see figure 7.2. (The uniform onset flow direction is distinct from the compressibility direction defined by record G5, see section B.2.1.) Note that the onset flow must be consistent with any flow symmetry specified in record G4; the program makes no check for consistency.

The global onset flow data can be input in one of two format options.

Format Option 1: Header Record and Parameter Values Records

| Header Record | <ALPHA> | <BETA> | <UINF> | <WM> | <WDC> | <WCP> | <SID> |
|---|---|---|---|---|---|---|---|
| Parameter Values: | alpha | beta | uinf | wm | wdc | wcp | sid |

The parameter values record can be repeated, each time defining a set of values for one solution. Each set of parameter values must be on a single record; record continuation is indicated by a plus (+) as the last character on a card. Any quantities not listed on the header card are omitted from the parameter values records. They will be given default values for all solutions. The header card can be repeated several times, each time defining different quantities for input for a different set of solutions.

Format Option 2: Separate Record for Each Parameter

<ALPHA = alpha(1), alpha (2),..., alpha(N)>
<BETA = beta(1), beta(2),..., beta(N)>
<UINF = uinf(1), uinf(2),..., uinf(N)>
<WM = wm(1), wm(2),..., wm(N)>
<WDC = wdcx(1), wdcy(1), wdcz(1), wdcx(2),..., wdcz(N)>
<WCP = wcpx(1), wcpy(1), wcpz(1), wcpx(2),..., wcpz(N)>
<SID = solution-id(1),..., solution-id(N)>

The ordering of these records is arbitrary. Each must be a single record; record continuation is indicated by a plus (+) as the last character on a card. The number of solutions is the maximum value of N from all records. Missing parameter values are given default values.

alpha = $\alpha$ = angle of attack defining the direction of uniform onset flow velocity (degrees); default = 0.
beta = $\beta$ = angle of sideslip defining the direction of uniform onset flow velocity (degrees); default = 0.
uinf = $U_{\infty}$ = magnitude of uniform onset flow velocity; default = 1.
wm = $\omega_m$ = magnitude of rotational onset flow velocity (radians/unit time); default = 0.

wdc = direction numbers of rotational velocity vector; default = 0., 1., 0.
wcp = coordinates of point locating rotational velocity vector; default = 0., 0., 0.
sid = solution-identification alphanumeric name (maximum of 20 characters, without embedded blanks)

Both UINF and UNIF are accepted by the program. The magnitude of rotational onset flow velocity (wm) must not be negative. The direction numbers (wdc) are normalized by the program to give the direction cosines. If the identification name is omitted, then the solution-identification is a blank label. Otherwise the solution-identification names must be unique. The program assigns ordering indices to each solution, consecutive and starting at 1. In subsequent records each solution can be referred to either by its ordering index or by its (non-blank) identification name.

Record Default: all parameter defaults for one solution.

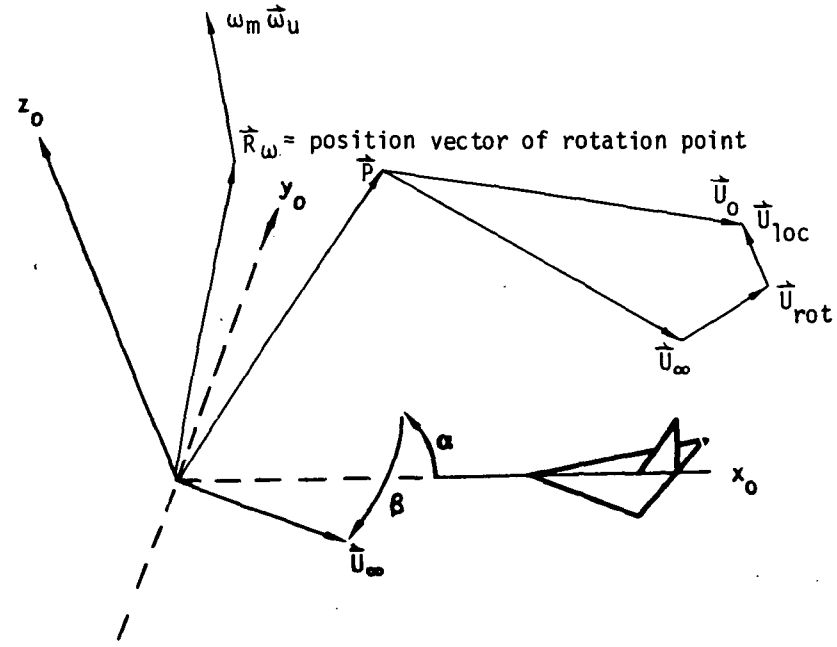
Restrictions: If the three direction numbers (wdc) are zero and the rotational velocity magnitude (wm) is non-zero, the program gives an error. The number of solutions cannot be more than 200. Format option 1 can not be used if only the solution-identification name is being specified.

Example (same data defined in both format options):
Format Option 1:

| ALPHA | BETA | WM | WCP | SID |
|---|---|---|---|---|
| 1., | 0., | 1., | 100.,0.,0., | ANGLE-OF-ATTACK |
| 0., | 1., | 1., | 100.,0.,0., | ANGLE-OF-SIDESLIP |

Format Option 2:

```
    ALPHA =1.
    BETA = 0.,1.
    WM = 1.,1.
    WCP = 100., 0.,0.,100., 0., 0.
    SID = ANGLE-OF-ATTACK, ANGLE-OF-SIDESLIP
```




Total onset flow = $\vec{U}_o = \vec{U}_\infty + \vec{U}_{rot} + \vec{U}_{loc}$

Reference coordinate system: $x_o$, $y_o$, $z_o$

Uniform onset flow: $\vec{U}_\infty = U_\infty (\cos\alpha \cos\beta, -\sin\beta, \sin\alpha \cos\beta)$

Rotational onset flow = $\vec{U}_{rot} = \omega_m \vec{\omega}_u \times (\vec{P} - \vec{R}_\omega)$

Rotational flow velocity, magnitude = $\omega_m$

Rotational flow velocity, direction cosines, $\vec{\omega}_u = (\omega_{nx}, \omega_{ny}, \omega_{nz})$

Position vector of point in flow field = $\vec{P}$

Position vector of rotation point = $\vec{R}_\omega$

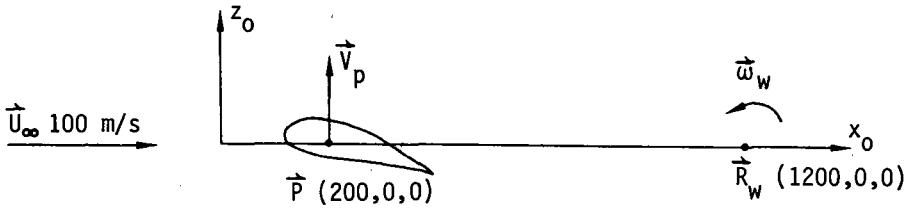
Global onset flow = $\vec{U}_\infty + \vec{U}_{rot}$

Local onset flow = $\vec{U}_{loc}$

Note: $\vec{\omega} = \omega_m \vec{\omega}_u$ is the negative of the vehicle rotation rate in a steady non-rotating flow

Figure 7.2 - Definition of total onset flow

Example of usage of rotational onset flow: Consider the quasi-steady effect of a wing pitching nose down about a point aft of the trailing edge as shown




Rotation rate of wing with respect to fluid = $\vec{\omega}_w$ = (.0,-.01,.0) rad/s

Rotation rate of fluid with respect to wing = $\vec{\omega}$ = (.0,+.01,.0) rad/s

The total onset flow of the fluid is

$$\vec{U}_o = \vec{U}_\infty + \vec{\omega} \times (\vec{P} - \vec{R}_\omega)$$

If this is divided by the uniform onset flow speed (in effect giving $U_\infty$ a unit value), the total onset flow is

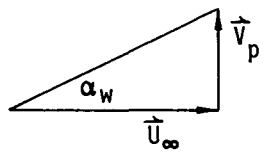
$$\frac{\vec{U}_o}{U_\infty} = \left(\frac{\vec{U}_\infty}{U_\infty}\right)_i + \left(\frac{\vec{\omega}}{U_\infty}\right)_i \times (\vec{P} - \vec{R}_\omega)$$

where the i subscript indicates the program input quantity. The corresponding PAN AIR input for the original and the scaled solutions would be

| ALPHA | BETA | UNIF | WM | WDC | WCP |
|---|---|---|---|---|---|
| 0. | 0. | 100. | .01 | 0.,+.01,0. | 1200.,0.,0. |
| 0. | 0. | 1. | .0001 | 0.,+.01,0. | 1200.,0.,0. |

Note that any specified flows (record set N17) and local onset flows (record set N18) must also be divided by $U_\infty$ in the scaled solution.

The flow angularity $\alpha_w$ seen by the wing at point P is due to the combined effect of $\vec{U}_\infty$ and $\vec{V}_p = \vec{\omega} \times (\vec{P}-\vec{R}_\omega)$. For the original solution




$$\tan \alpha_w = \frac{V_p}{U_\infty} = \frac{10.}{100.} = .1$$

In the scaled solution the flow angularity is unchanged since both velocities are divided by $U_\infty$

$$\tan \alpha_w = \frac{(V_p/U_\infty)}{(U_\infty/U_\infty)} = \frac{.1}{1.} = .1$$

Record G7. Tolerance for Geometric Edge Matching

This record specifies the tolerance distance which is used by the automatic network edge abutment capability to define abutments. This capability specifies strength matching boundary conditions and inserts gap-filling panels which eliminate gaps or overlaps between abutting network edges (see section B.3.5). The network edges or portions of edges which are within the geometric edge matching tolerance are assumed to abut. The automatic edge matching procedure can be suppressed (1) for individual network edges by using the Remove Doublet Edge Matching Option (record N13) or (2) globally by giving a negative value to the present tolerance distance. (The magnitude of the tolerance distance is also the default value for the Triangular Panel Tolerance, record N7). Alternately the abutment procedure can be accomplished by specification of abutments in the Geometric Edge Matching Data Group (section 7.5), which overrides the automatic capability for the edge abutments specified there.

<TOLERANCE FOR GEOMETRIC EDGE MATCHING = {tolerance}>

Record Default: tolerance = 0.

Examples:

```
TOLERANCE FOR GEOMETRIC EDGE MATCHING = .01
TOLE = .02
```

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Records G8 to G16 globally specify several options and parameters for the Network and the Flow Properties Data Groups. These records can be used to avoid repeatedly specifying the same records in those data groups. The global options and parameter values are used unless overridden locally in those data groups. Table 7.3 shows the data groups and subgroups in which these records are repeated.

| Record | Network Data Group | Flow Properties Data Group | |
|---|---|---|---|
| | | Surface Flow Properties | Forces and Moments |
| G8. Surface Selection Option(s) | | SF5 | FM12* |
| G9. Selection of Velocity Computation Method | | SF6 | FM13 |
| G10. Computation Option for Pressures | | SF7 | FM14 |
| G11. Velocity Correction Options | | SF10b<br>SF11b | FM15 |
| G12. Pressure Coefficient Rules | | SF10c<br>SF11c | FM16 |
| G13. Ratio of Specific Heats | | SF8 | FM17 |
| G14. Reference Velocity for Pressure | | SF9 | FM18 |
| G15. Store Velocity Influence Coefficient Matrix | N3 | | |
| G16. Store Local Onset Flow | N4 | | |

* One option only

Table 7.3 - Subsequent records which refer to global options and parameters specified in records G8 to G16

Records G8 to G12 allow selection of several options for the calculation of flow quantities: velocities, pressure coefficients, and force and moment coefficients. The calculations will be made for all combinations of the selected options (and all subsequently selected solutions). Care should be used in selecting the number of possible options, since the use of all options can result in a large amount of output. For example, specification of all options available in these records will result in 150 sets of results for each solution and for each specified case of surface flow properties calculations.

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Record G8. Surface Selection Options

These options specify the network surfaces or surface combinations for which flow quantities and pressure (and force and moment) coefficients are to be computed. Several options can be selected, resulting in multiple calculations.

```
<SURFACE SELECTION = {{ Surface(s)}} >
                     UPPER
                     LOWER
                     UPLO          (upper minus lower)
                     LOUP          (lower minus upper)
                     AVERAGE
```

According to the instruction, the computations of surface flow properties will give the flow quantities and pressure coefficients on a surface (UPPER or LOWER), the difference between the values on the two surfaces (UPLO or LOUP), and the average value on the two surfaces (AVERAGE). For the computations of forces and moments, the LOUP and AVERAGE options are equivalent to the UPLO option, see discussion on record FM12. (The upper surface of a network is that on which the normal vector points outward, see section B.1.1). For example, if the user wants the difference in pressure coefficients between the upper and lower surfaces and the flow quantities (for example, local Mach number) on the upper surface, then the UPLO and UPPER options should be selected.

Record Default: UPPER surface only

Examples:

```
SURFACE SELECTION = UPPER, UPLO
SURF = LOWE
```

Record G9. Selection of Velocity Computation Method

This record selects one or two velocity computation methods, see section B.4.1. The BOUNDARY-CONDITION method uses the boundary condition equations and is relatively inexpensive. (The specific procedure used by this method is specified by record N10 for each network.) The VIC-LAMBDA method uses the velocity influence coefficient matrices. To use this method the VIC matrices must be stored, either globally (record G15) or individually (record N3) for non-wake networks. The VIC-LAMBDA method must be used for a network if an edge force calculation (record FM9) is requested in the forces and moments calculations. Both methods can be selected, resulting in multiple calculations.

```
< SELECTION OF VELOCITY COMPUTATION =   {{Method(s)}}>
                                          BOUNDARY-CONDITION
                                          VIC-LAMBDA
```

Record Default: BOUNDARY-CONDITION method only

Examples:

```
SELECTION OF VELOCITY COMPUTATION = VIC-LAMBDA
SELE = BOUN, VIC
```

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Record G10. Computation Option for Pressures

This record selects a preferred direction, which is required by several relations used to compute pressure coefficients and local Mach numbers, see section B.4.2. The option does not change the velocities, but does change some of the calculated pressure coefficients. For example, the linearized pressure coefficient rule

$$C_p = -\frac{2u}{U_\infty}$$

requires the definition of u, the perturbation velocity component in the preferred direction.

< COMPUTATION OPTION FOR PRESSURES = {Option} >
UNIFORM-ONSET-FLOW
TOTAL-ONSET-FLOW
COMPRESSIBILITY-VECTOR

For the first and second options, the preferred direction is that of the uniform onset flow (record G6). For the second option only, any incremental onset flows, including rotational (record G6) and local (record N18) onset flows, are included in the pressure coefficient and local Mach number relations, see section B.4.2. The local onset flows are used only if they are stored, either globally (record G16) or individually (record N4) for each network. Note that the first two options are solution dependent (see section N.5 of the Theory Document). For the third option, the preferred direction is the compressibility direction (record G5).

Record Default: UNIFORM-ONSET-FLOW option

Restrictions: If the UNIFORM-ONSET-FLOW option is selected and uinf=0. (record G6), then a warning will be printed, the UNIF option will be replaced by the COMP option, and execution will continue. If the COMPRESSIBILITY-VECTOR option is selected and the Mach number is less than 0.1 (record G5), a warning will be printed and execution will continue.

Examples:

```
COMPUTATION OPTION FOR PRESSURES=TOTAL-ONSET-FLOW
COMP = UNIF
```

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Record G11. Velocity Correction Options

This record specifies possible velocity corrections. The corrections are used in stagnation or near-stagnation conditions where the small perturbation assumptions are violated (see section B.4.1). For incompressible flow the corrections are null; this record should be omitted. The first correction (SA1) is used for thick unswept wings or flow-through nacelles. The second correction (SA2) is used in connection with a subsequent boundary layer analysis of thick wings or wing-like configurations. Several options can be selected, resulting in multiple calculations.

< VELOCITY CORRECTIONS = {{Correction(s)}}>

NONE
SA1
SA2

Record Default: NONE only

Examples:

```
VELOCITY CORRECTIONS = NONE,SA1
VELO = SA2
```

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Record G12. Pressure Coefficient Rules

This record specifies the rules to be used to calculate the pressure coefficients (also force and moment coefficients) and local Mach numbers. The corresponding relations are listed in section B.4.2. Several rules can be selected, resulting in multiple calculations.

```
< PRESSURE COEFFICIENT RULES =   {{ Rule(s)}} >
                                   ISENTROPIC
                                   LINEAR
                                   SECOND-ORDER
                                   REDUCED-SECOND-ORDER
                                   SLENDER-BODY
```

For incompressible flow the isentropic relation is equivalent to the reduced second-order relation.

Record Default: ISENTROPIC rule only

Examples:

```
PRESSURE COEFFICIENT RULES = ISENTROPIC,SECOND-ORDER
PRES = LINE
```

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Record G13. Ratio of Specific Heats

This record specifies values of the ratio of specific heats, which are used in the SA1 velocity correction (record G11), and in the pressure coefficient and local Mach number relations. For incompressible flow the ratio is not used; this record should be omitted. A set of values can be input, one for each solution defined in record G6.

< RATIO OF SPECIFIC HEATS = {{gamma(s)}} >

Parameter Default: gamma = 1.4 for all solutions not in the list above.

Record Default: gamma = 1.4 for all solutions.

Restrictions: gamma = 0. gives an error. If the number of values is greater than the number of solutions (record G6), the program gives an error.

Examples:

```
RATIO OF SPECIFIC HEATS = 1.4, 1.667
RATI = 1.286
```

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Record G14. Reference Velocity for Pressure

This record is used only if UINF is zero in record G6. (Otherwise UINF is the pressure reference velocity.) This record specifies values of the reference velocity which is used in calculation of pressure coefficients (see section B.4.2) and force and moment coefficients (see section B.4.3). A set of values can be input, one for each solution defined in record G6.

< REFERENCE VELOCITY FOR PRESSURE = {{rvp(s)}}>

Parameter Default: rvp = uinf (record G6) for all solutions not in the list above.

Record Default: rvp = uinf (record G6) for all solutions.

Restrictions: rvp = 0. gives an error. If the number of values is greater than the number of solutions (record G6), the program gives an error.

Examples:

```
REFERENCE VELOCITY FOR PRESSURE = .5
REFE = 2.,1.,10.
```

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Records G15 and G16 instruct the program to store the indicated data for each non-wake network. These records also appear in the Network Data Group where storage may be specified for individual networks.

Record G15. Store Velocity Influence Coefficient Matrix

This record specifies the storage (and computation if necessary) of the velocity influence coefficient matrix for all non-wake networks (see section B.4.1) . This can significantly increase the computer storage requirements and should be avoided unless the data are needed for subsequent calculations. The VIC matrix must be stored for each network where the velocities are to be computed by the VIC-LAMBDA method (record G9) or where an edge force calculation (record FM9) is to be used for the network.

<STORE VIC MATRIX>

Record Default: The VIC matrix is not stored on a global basis.

Record G16. Store Local Onset Flow

This record specifies the storage of the local onset flow (record set N18) for the all networks where defined. This can significantly increase the computer storage requirements. These flows must be stored if they are to be used in calculation of the pressure, and force and moment coefficients and local Mach numbers. (The use of local onset flows in the right-hand side(s) of the boundary condition equations is not affected by the present record. Also this record does not affect rotational onset flows, record G6, which are always stored.)

<STORE LOCAL ONSET FLOW>

Record Default: Local onset flow is not stored on a global basis.

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Record G17. Checkout Print Options

This record specifies various printout options related to input data checkout. (These are separate from program calculation output options, which are defined in sections 7.6 and 7.7.) The program modules and checkout print options are listed in table 7.4. The checkout print options are described in more detail in the description of the printed output in section 8.2.

<CHECKOUT PRINTS = {Module(1), List(1), Module(2), List(2)}>

Module(I) are the module names listed in the first column in table 7.4.
List(I) are the option numbers listed in the second column in table 7.4.

Parameter Defaults: The modules will have defaults listed in table 7.4.

Record Default: The module defaults listed in table 7.4.

Examples:
CHEC = DIP,1,2,3
CHECKOUT PRINTS = ALL

| Module | Options (one or more per module) | Defaults |
|---|---|---|
| DIP | 1 Warning messages<br>2 Input records<br>3 Global data summary | 1<br>2 |
| DQG | 1 Warning messages<br>2 Corner point data<br>3 Enriched grid<br>4 Abutments with empty space<br>5 Other Abutments<br>6 Control point data<br>7 Boundary Conditions | 1<br>2<br><br>4<br><br>6 |
| DEL | Delete all above printout | |
| ALL | Select all above printout | |

Table 7.4 - Checkout print options (record G17)

## 7.4 Network Data Group

This data group specifies the individual networks which model the physical and wake boundaries of the configuration. There is no restriction on the order of appearance of the individual networks of a configuration. The input data for each network are independent of those for the other networks, with one possible exception allowed in record N9. The number of networks must not be more than 100.

A network is defined by a rectangular array of grid points which are the corner points of quadrilateral panels. The grid definition scheme is discussed in detail in sections 3.2 and B.1.1. The network size is defined by the numbers of rows (M) and columns (N) of grid points. The identification of the rows and columns is chosen by the user. For the input data the grid points are ordered as follows: all points on the first column in the order of the rows, followed by all points in the second column in the order of the rows, and so forth until the array is complete, see figure 7.3. The array of grid points may be triangular, that is, one edge may be a single point ("a collapsed edge"). However the grid points must be defined as a rectangular array with the common edge point defined repeatedly.

The ordering of the grid points also establishes the indexing of the network edges, as shown in figure 7.3. With this indexing the first column of grid points forms edge 4; the last column of grid points forms edge 2. The indexed ordering of the network edges also establishes the "upper" and "lower" surfaces of the network. With the column vector $\bar{M}$ along edge 4 and the row vector $\bar{N}$ along edge 1, then the product ($\bar{N} \times \bar{M}$) defines the positive direction of the panel normal vectors. The panel normal vectors point outward from the upper surface. Alternately, figure 7.3 with the edges ordered in a counter-clockwise manner is a view of the upper surface.

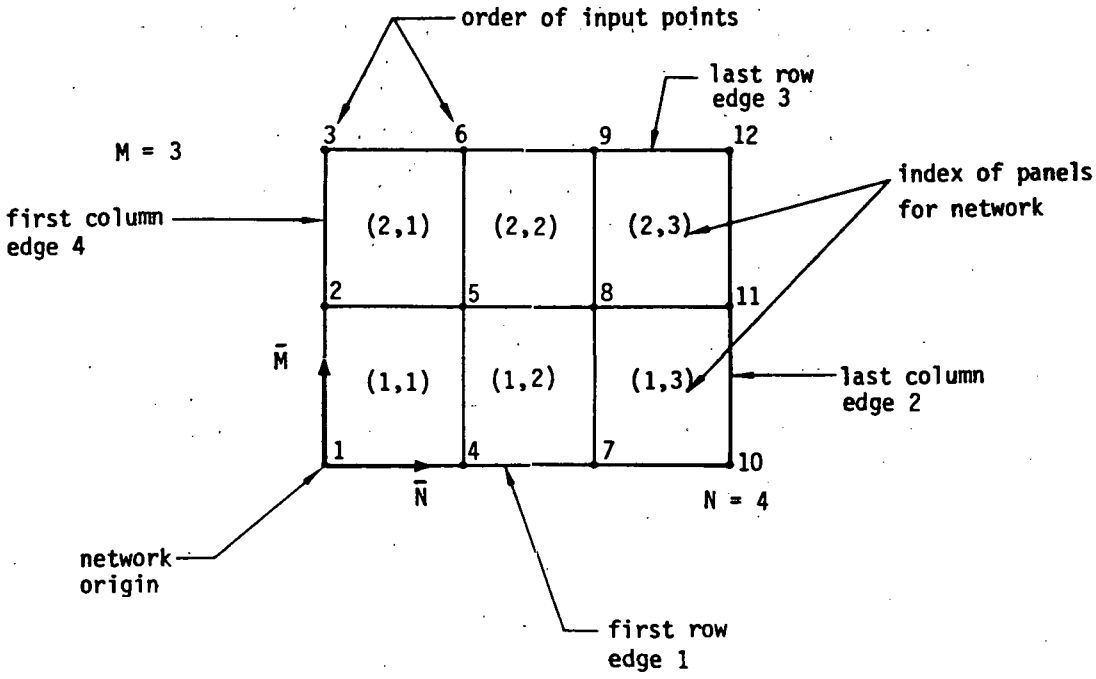
Ordering: The first record in the network data group must be the group identifier, record N1. Records N2 to N18 are repeated for each network. For each network the first record must be the network identifier record set N2. The other records can appear in any order, except for restrictions within record sets N14 to N18. (The records have the following organization: record N2 defines the network, records N3 to N8 give general information, and records N9 to N18 give boundary condition information.)

Record N1. Network Data Group Identifier

This record identifies the data group and must be the first record.

< BEGIN NETWORK DATA >

Record Default: No network data (that is, a post-solution update run) in which case all records in the Network Data Group are omitted.




Note: The viewer is looking at the upper surface since $\bar{N} \times \bar{M}$ points toward the viewer.

Figure 7.3 - Illustration of input ordering of panel corner points and indexing of network edges

Record Set N2. Network Identifier Record Set

This record set specifies basic network information and must appear first in the block of records (N2 to N18) for each network.

Record N2a. Network Identifier

This record identifies the network and specifies options related to possible update runs, which are described in section 7.2.3.

NETWORK = List(n)

Option 1: Original Specification or Addition of a New Network

List(1) = <network-id> {number-rows, number-columns} <NEW>

Parameter Defaults: The alphanumeric network-id name can be omitted (see below). The secondary keyword NEW is the default and can be omitted.

Option 2: Replacement of Existing Network with New Network (IC update only)

List(2) = {network-id, number-rows, number-columns} REPLACE

Option 3: Definition of New Right-Hand Side Data (IC and Solution updates)

List(3) = {network-id} SOLUTION-UPDATE

Option 4: Deletion of a Network (IC update only)

List(4) = {network-id} DELETE

Under Option 2, all data for the existing network are eliminated; all required input data must be specified for the replacing network. Under Option 3, all existing solution data are eliminated; only the right-hand side data can be and must be defined: records N14 to N18. Under Option 4, there must be no other input records for the network.

The "network-id" is an alphanumeric name (maximum of 20 characters, without embedded blanks). If omitted in the original specification of a network, then the network-id name is a blank label. Otherwise, the network-id name must be unique. The program assigns an ordering index to each network, consecutively and starting at 1. In an IC update run, new networks are similarly indexed starting with the next available index; a replacing network is assigned the index of the network being replaced; deletion of a network does not result in the reindexing of the other networks. In subsequent data groups and in later update runs, each network can be referred to either by its ordering index or by its (non-blank) network-id name.

The "number-rows" and "number-columns" are numbers of rows (M) and columns (N) of grid points, figure 7.3.

Examples:

```
NETWORK = OUTBOARD-WING 6  7
NETW = VERTICAL-TAIL, 11, 8, REPL
NETWORK = INBOARD-WING-3, SOLUTION-UPDATE
NETW = WING-A4, DELE
```

Record N2b. Grid Point Coordinates

This record specifies the coordinates of the network grid points, which completely define the network geometry.

{x(1), y(1), z(1), x(2), y(2), z(2),...}

The coordinates of the grid points must be specified in the reference coordinate system, see section B.2.1. The grid points must be in the proper order: all points of the first column in the order of the rows, all points of the second column in the order of the rows, and so forth. The ordering is illustrated in figure 7.3. The total number of grid points is the product of the numbers of rows (M) and columns (N) specified in record N2a.

Restrictions: The coordinates occur in triplets which either must be together on the same card or else record continuation must be indicated by a plus (+) as the last character on the card.

Records N3 and N4 instruct the program to store particular data for subsequent use. These two records can be input in the Global Data Group. If the records were input there, repetition of the records here is unnecessary.

Record N3 (and record G15). Store Velocity Influence Coefficient Matrix

This record specifies the calculation and storage of the VIC matrix for the network. (For wake networks both record N3 (or record G15) and record N6 are required for this.) This can significantly increase the computer storage requirements and should be avoided unless needed. The VIC matrix must be stored if velocities are to be computed by the VIC-LAMBDA method (record G9) or if an edge force calculation (record FM9) is to be used for the network.

<STORE VIC MATRIX>

Record Default: VIC matrix not stored, unless specified by record G15.

Record N4 (and record G16). Store Local Onset Flow

This record specifies the storage of the local onset flow for the network. The local onset flow must be stored if it is to be used in the computation of the pressure coefficients (also force and moment coefficients) and the local Mach numbers. This can significantly increase the computer storage requirements.

<STORE LOCAL ONSET FLOW>

Record Default: Local onset flow not stored, unless specified by record G16.

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Record N5. Reflection in Plane of Symmetry Tag

This record identifies if the network is in a plane of configuration symmetry in which case the network reflection requires special treatment to avoid a singular AIC. Omit this record if there are no planes of configuration symmetry (record G4). This record can be omitted if the entire network is closer to the plane of symmetry than the magnitude of the geometric edge matching tolerance (record G7), since the reflection will be automatically tagged. Network reflection rules and restrictions are discussed in section B.2.3.

<SYMMETRY PLANE NETWORK = {Plane}>
FIRST-PLANE
SECOND-PLANE

The "Plane" option specifies the plane in which reflection is to be specially treated. The first and second planes of symmetry are defined by record G4.

Record Default: The network will be reflected in all defined planes of configuration symmetry without special treatment, unless the reflection is tagged automatically by the program.

Examples:

```
SYMMETRY PLANE NETWORK = FIRST-PLANE
SYMM = SECO
```

Record N6. Wake Flow Properties Tag

Omit this record for non-wake networks. This record instructs the program to calculate and store data for calculations on a wake network. Specifically, the potential and (normal) velocity influence coefficient matrices are calculated from the average potential and the average normal mass flux on a wake network. If the storage of the VIC matrix is requested (record N3 or record G15), then the VIC matrix is also calculated. This option allows calculation of the wake flow properties in the post-solution calculations of surface flow properties and of forces and moments.

<WAKE FLOW PROPERTIES TAG>

Record Default: The wake influence coefficient matrices are not stored.

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Record N7. Triangular Panel Tolerance

This record specifies a tolerance length for the automatic program check on "almost triangular" panels. (The program searches for panel edges whose length is less than the specified tolerance, in which case the edge is collapsed making the quadrilateral panel into a triangle, see section B.1.3.)

<TRIANGULAR PANEL TOLERANCE = {tolerance}>

Record Default: The triangular panel tolerance is set equal to the modulus of the geometric edge matching tolerance (record G7).

Examples:

```
TRIANGULAR PANEL TOLERANCE = .001
TRIA = .02
```

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Record N8. Network and Edge Update Tag

This record tags either the entire network or selected edges for updating. This allows updating of the network or its abutting neighbors in future computer runs. If not tagged, the network cannot be replaced or deleted in a subsequent IC update run (options 2 and 4 in record N2a). If the edges are not tagged, they cannot abut a network which is added, replaced or deleted in a subsequent IC update run (options 1, 2 and 4 in record N2a). Any network edge which abuts an updateable network but is not tagged as updateable will be identified by a warning message in the DQG module. (The abutting edges include those whose corner control points abut the network to be updated.) In an IC update, all new and replacing networks (options 1 and 2 in record N2a) must be tagged. Also, if the closure condition (record set N14) is specified on a network, then that network (but not the abutting edges of neighboring networks) must be tagged as updateable. Note two points: (1) an entire configuration must not be tagged as updateable, and (2) update tags will increase the program cost.

<UPDATE TAG = <edge-number-list>>

If the edge-number-list is omitted, then the network and all edges are tagged for updating. If one or more edge numbers are listed, then those edges (and no other part of the network) are tagged. The network edge indices are identified in figure 7.3.

Record Default: The network is not tagged for updating.

Examples:

```
UPDATE TAG
UPDA = 1, 4
```

Record N9. Boundary Condition Specification

This record specifies the boundary condition class and associated subclass for the network. The boundary condition class must be one of five standard classes (see sections 3.3 and B.3.1).

Class 1 - Impermeable Surface Mass Flux Analysis
Class 2 - Specified Normal Mass Flux Analysis
Class 3 - Specified Tangential Velocity Design
Class 4 - Selected Terms
Class 5 - General Boundary Condition Equation

The associated subclass specifies the specific boundary condition equations. Figures 7.4 to 7.6 describe boundary condition classes 1 to 3, including the subclass identifiers (integer or keyword), subclass descriptions, boundary condition equations and associated singularity types (record N11). Figure 7.7 describes boundary condition class 4, including the individual terms of the general boundary condition equation (see section B.3.1), the corresponding coefficient values, and the identifying indices.

< BOUNDARY CONDITION = <Level> {Class} {{Subclass(es)}} >
LOCAL
OVERALL

Default Parameter: LOCAL

The level instruction allows the user to establish default class and subclass(es) which will also apply to subsequent networks. The level OVERALL establishes the record default, which can be changed by a subsequent record with the level OVERALL. The level LOCAL allows specification of the class and subclass(es) for one network, without changing the default values.

Class = one of the values 1 to 5

Subclass(es) = index or keyword listed in columns 1 and 2 of figures 7.4 and 7.6; or pair of indices listed in the last column of figure 7.7.

For classes 1, 2 and 3, figures 7.4 to 7.6, a single subclass is specified; the subclass defines both boundary condition equations. For class 4, figure 7.7, two boundary conditions equations, each with two "subclasses" must be specified. Each "subclass" is a pair of numbers: one for the left and one for the right-hand side of the equation. Exception: if a wake network is specified in record N11, the appropriate doublet boundary conditions are assumed; only one "subclass" need be specified. For class 5, there are no subclasses; the boundary condition equations are specified entirely by record set N15.

Record Default: The class and subclass(es) of the previous network boundary condition specification record N9 with the level "OVERALL."

Examples:

```
    BOUNDARY CONDITION = 1,4          }
    BOUNDARY CONDITION = 1, WAKE 1    }---> equivalent
    BOUNDARY CONDITION = OVERALL 2 4
    BOUN = LOCA, 3, UPPER
    BOUNDARY CONDITION = 5
    BOUN = 4, 4 1, 6 3
```

The last example, for class 4, is interpreted as: boundary condition class 4, term 4 on the left and term 1 on the right-hand side of the first equation, term 6 on the left and term 3 on the right hand side of the second equation, see figure 7.7. The resulting two equations are those of class 1, subclass 1, see figure 7.4.

| SUBCLASS INDEX | SUBCLASS KEYWORD | SUBCLASS DESCRIPTION | BOUNDARY CONDITION EQUATIONS | SINGULARITY TYPES |
|---|---|---|---|---|
| 1 | UPPER | Impermeable Upper Surface | $\sigma = -\vec{U}_o \cdot \hat{n}$ | SA |
| | | | $\phi_L = 0$ | DA |
| 2 | LOWER | Impermeable Lower Surface | $-\sigma = -\vec{U}_o \cdot \hat{n}$ | SA |
| | | | $\phi_U = 0$ | DA |
| 3 | AVERAGE | Impermeable Average (Cambered) Surface | $\sigma = 0$ | NOS |
| | | | $\vec{w}_A \cdot \hat{n} = -\vec{U}_o \cdot \hat{n}$ | DA |
| 4 | WAKE 1 | Wake 1 (with spanwise variation) | $\sigma = 0$ | NOS |
| | | | $\mu$ = leading edge values | DW1 |
| 5 | WAKE 2 | Wake 2 (without spanwise variation) | $\sigma = 0$ | NOS |
| | | | $\mu$ = corner point value | DW2 |

UPPER and LOWER surfaces: see section B.1.1

Singularity Types: see section B.3.4

Figure 7.4 - Class 1 (impermeable mass flux analysis) boundary condition subclasses

| SUBCLASS | | SUBCLASS | BOUNDARY CONDITION | SINGULARITY |
|---|---|---|---|---|
| INDEX | KEYWORD | DESCRIPTION | EQUATIONS | TYPES |
| 1 | UPPER | Specified Normal Mass Flux on Upper Surface | $\sigma = -\vec{U}_o \cdot \hat{n} + \beta_{n1}$ | SA |
| | | | $\phi_L = 0$ | DA |
| 2 | LOWER | Specified Normal Mass Flux on Lower Surface | $-\sigma = -\vec{U}_o \cdot \hat{n} + \beta_{n1}$ | SA |
| | | | $\phi_U = 0$ | DA |
| 3 | DEFLECTION | Linearized Deflection on Average (Cambered) Surface | $\sigma = 0$ | NOS |
| | | | $\vec{w}_A \cdot \hat{n} = -\vec{U}_o \cdot \hat{n} + \beta_{n2}$ | DA |
| 4 | THICKNESS | Thickness on Average (Cambered) Surface | $\sigma = \beta_{n1}$ | SA |
| | | | $\vec{w}_A \cdot \hat{n} = -\vec{U}_o \cdot \hat{n}$ | DA |
| 5 | BOTH | Both Deflection and Thickness on Average Surface | $\sigma = \beta_{n1}$ | SA |
| | | | $\vec{w}_A \cdot \hat{n} = -\vec{U}_o \cdot \hat{n} + \beta_{n2}$ | DA |

UPPER and LOWER surfaces: see section B.1.1

Singularity Types: see section B.3.4

Figure 7.5 - Class 2 (specified normal mass flux analysis) boundary condition subclasses

| SUBCLASS INDEX | SUBCLASS KEYWORD | SUBCLASS DESCRIPTION | BOUNDARY CONDITION EQUATIONS | SINGULARITY TYPES |
|---|---|---|---|---|
| 1 | UPPER | Upper Surface Design | $\vec{t}_U \cdot \vec{v}_U = -\vec{t}_{t1} \cdot \vec{U}_o + \beta_{t1}$ | SA |
| | | | $\phi_L = 0$ | DD1 |
| 2 | LOWER | Lower Surface Design | $\vec{t}_L \cdot \vec{v}_L = -\vec{t}_{t1} \cdot \vec{U}_o + \beta_{t1}$ | SA |
| | | | $\phi_U = 0$ | DD1 |
| 3 | THICKNESS | Linearized Design on Average (Cambered) Surface | $\vec{t}_A \cdot \vec{v}_A = -\vec{t}_{t1} \cdot \vec{U}_o + \beta_{t1}$ | SD1 |
| | | | $\vec{w}_A \cdot \hat{n} = -\vec{U}_o \cdot \hat{n} + \beta_{n2}$ | DA |
| 4 | CAMBER | Camber Design with Thickness | $\sigma = \beta_{n1}$ | SA |
| | | | $\vec{t}_D \cdot \vec{\nabla}\mu = \beta_{t2}$ | DD1 |
| 5 | THICKNESS CAMBER | Thickness and Camber Design | $\vec{t}_A \cdot \vec{v}_A = -\vec{t}_{t1} \cdot \vec{U}_o + \beta_{t1}$ | SD1 |
| | | | $\vec{t}_D \cdot \vec{\nabla}\mu = \beta_{t2}$ | DD1 |
| 6 | BOTH | Both Upper and Lower Surface Design on Average Surface | $\vec{t}_U \cdot \vec{v}_U = -\vec{t}_{t1} \cdot \vec{U}_o + \beta_{t1}$ | SD1 |
| | | | $\vec{t}_L \cdot \vec{v}_L = -\vec{t}_{t2} \cdot \vec{U}_o + \beta_{t2}$ | DD1 |

UPPER and LOWER surfaces: see section B.1.1

Singularity Types: see section B.3.4

Figure 7.6 - Class 3 (specified tangential velocity design) boundary condition subclasses

PROBLEM TYPE - MASS FLUX ANALYSIS

| Quantity | Term | Coefficient | Index |
|---|---|---|---|
| Left-hand Side | | | |
| Upper Surface | $\vec{w}_U \cdot \hat{n}$ | $a_U = 1$ | 1 |
| Lower Surface | $\vec{w}_L \cdot \hat{n}$ | $a_L = 1$ | 2 |
| Average Surface | $\vec{w}_A \cdot \hat{n}$ | $a_A = 1$ | 3 |
| Difference | $\sigma$ | $a_D = 1$ | 4 |
| Right-hand side | $b_n \vec{U}_o \cdot \hat{n}$ | $b_n = -1$ | 1 |
| | | $b_n = 1$ | 2 |
| | | $b_n = 0$ | 3 |

PROBLEM TYPE - POTENTIAL

| Quantity | Term | Coefficient | Index |
|---|---|---|---|
| Left-hand side | | | |
| Upper Surface | $\phi_U$ | $c_U = 1$ | 5 |
| Lower Surface | $\phi_L$ | $c_L = 1$ | 6 |
| Average Surface | $\phi_A$ | $c_A = 1$ | 7 |
| Difference | $\mu$ | $c_D = 1$ | 8 |
| Right-hand side* | $b_p \vec{U}_\infty \cdot \vec{\Psi}$ | $b_p = -1$ | 1 |
| | | $b_p = 1$ | 2 |
| | | $b_p = 0$ | 3 |

* $\vec{\Psi} = (x/s\beta^2, y, z)$

Figure 7.7 - Class 4 (selected terms) boundary condition subclasses

PROBLEM TYPE - VELOCITY DESIGN

| Quantity | Term | Coefficient | Index |
|---|---|---|---|
| Left-hand Side | | | |
| Upper Surface | $\vec{t}_U \cdot \vec{v}_U$ | $\vec{t}_U \neq 0$ | 9 |
| Lower Surface | $\vec{t}_L \cdot \vec{v}_L$ | $\vec{t}_L \neq 0$ | 10 |
| Average Surface | $\vec{t}_A \cdot \vec{v}_A$ | $\vec{t}_A \neq 0$ | 11 |
| Difference | $\vec{t}_D \cdot \vec{\nabla}\mu$ | $\vec{t}_D \neq 0$ | 12 |
| Right-hand side | $b_t \vec{t}_t \cdot \vec{U}_o$ | $b_t = -1$ | 1 |
| | | $b_t = 1$ | 2 |
| | | $b_t = 0$ | 3 |

PROBLEM TYPE - VELOCITY ANALYSIS

| Quantity | Term | Coefficient | Index |
|---|---|---|---|
| Left-hand side | | | |
| Upper Surface | $\vec{v}_U \cdot \hat{n}$ | $e_U = 1$ | 13 |
| Lower Surface | $\vec{v}_L \cdot \hat{n}$ | $e_L = 1$ | 14 |
| Average Surface | $\vec{v}_A \cdot \hat{n}$ | $e_A = 1$ | 15 |
| Difference | $\vec{v}_D \cdot \hat{n}$ | $e_D = 1$ | 16 |
| Right-hand side | $b_n \vec{U}_o \cdot \hat{n}$ | $b_n = -1$ | 1 |
| | | $b_n = 1$ | 2 |
| | | $b_n = 0$ | 3 |

For any problem type, one of the four left-hand side options and one of the three corresponding right-hand side options are selected for each equation. The potential boundary conditions include those on perturbation potential (bp = 0) and on total potential (bp = -1). Specified flows (ß terms) can be added separately to the right-hand side. The options allow specification of all quantities except tangent vectors (record N16) and specified flows (record N17).

Figure 7.7 Concluded

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Record N10. Method of Velocity Computation

Omit this record for boundary condition classes 1, 2 and 3. For wake networks record N10 should be omitted; the velocity computation is specified by record N6. This record instructs the program to compute and store data necessary for computing velocities from the boundary condition equations (record G9, option BOUNDARY-CONDITION), see section B.4.1. Use of the present record results only in the computation and storage of data; other records (G9, SF6 and FM13) select the procedure to be used for the velocity computation.

< METHOD OF VELOCITY COMPUTATION = {Method} >
LOWER-SURFACE-STAGNATION
UPPER-SURFACE-STAGNATION
NONSTAGNATION

The method is determined by the form of the boundary condition equations. If the perturbation potential is zero on the lower/upper network surface, then the LOWER/UPPER-SURFACE-STAGNATION option should be selected. Otherwise the NONSTAGNATION option should be selected.

Record Default: For class 1, 2 and 3 boundary conditions the data is computed and stored by the method: LOWER-SURFACE-STAGNATION for subclass 1, UPPER-SURFACE-STAGNATION for subclass 2, and NONSTAGNATION for the other subclasses. For class 4 and 5 boundary conditions the default is the NONSTAGNATION option.

Examples:

```
METHOD OF VELOCITY COMPUTATION = UPPER-SURFACE-STAGNATION
METH = NONS
```

Record N11. Singularity Types

Omit this record for class 1, 2 and 3 boundary conditions; the singularity types are specified by the subclass, figures 7.4 to 7.6. This record must be input for class 4 and 5 boundary conditions. This record specifies the singularity types, and the corresponding arrays of boundary condition location points, for both the source and doublet distributions. The user must select one singularity type for the source and one for the doublet distribution. The possible singularity arrays are shown in figure 7.8. (Notation: DW1 = doublet wake, number 1, see table 8.1). The types NOS and NOD are used when the source or doublet singularity strengths, respectively, are zero on the network.

| < SINGULARITY TYPES = | {Source} | {Doublet}> |
|---|---|---|
| | NOS | NOD |
| | SA | DA |
| | SD1 | DD1 |
| | | DW1 |
| | | DW2 |

Examples:

SINGULARITY TYPES = SA, DD1
SING = DW1, NOS

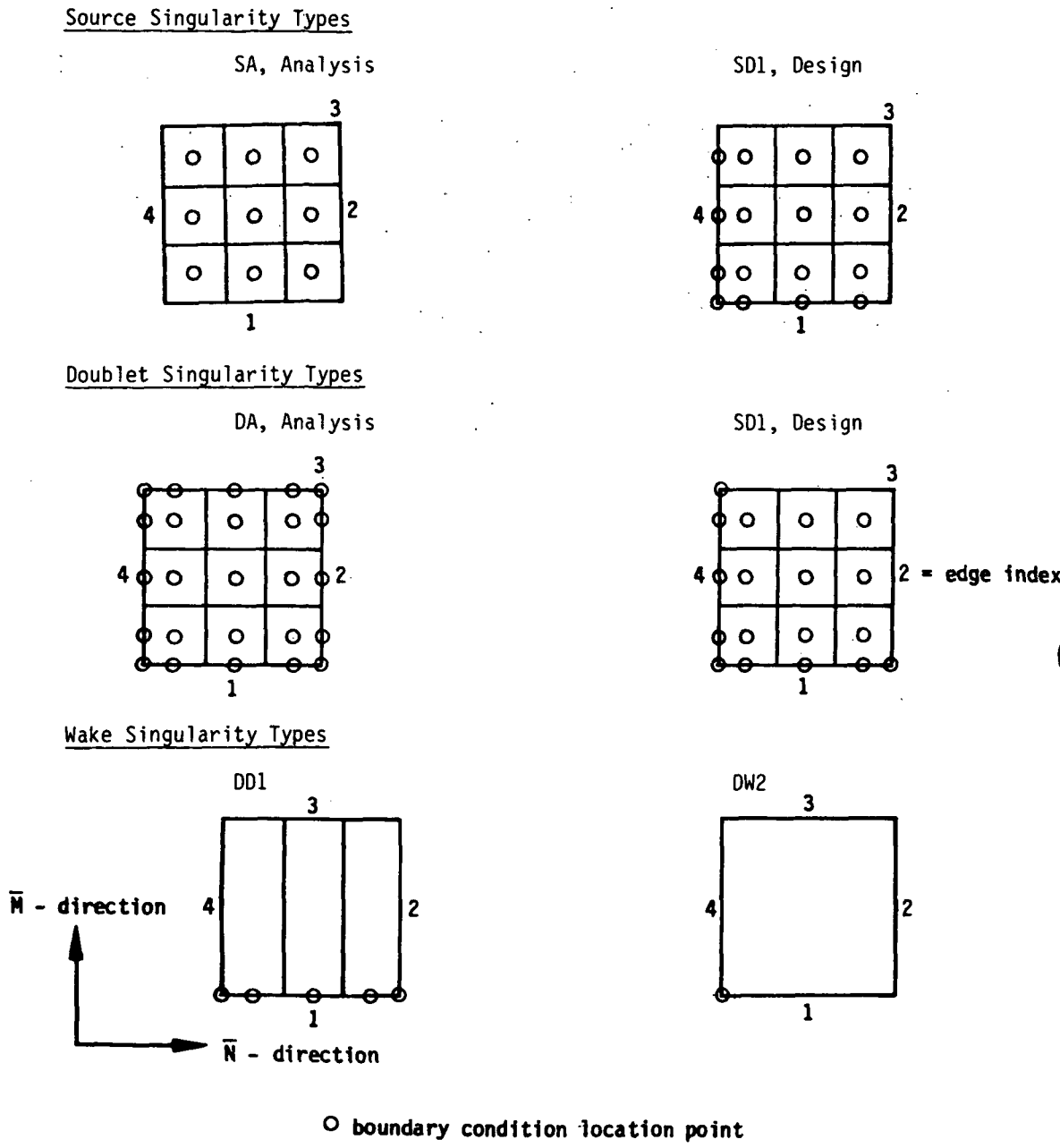


Figure 7.8 - Singularity types: boundary condition location point arrays on a sample network (record N11)

Record N12. Edge Control Point Locations

This record changes the network edge location of the boundary condition location points from the default positions shown in figure 7.8. The default location of the points is determined by the edge indexing, which is determined by the input ordering of the network grid points. If needed, the boundary condition location points on a network edge can be relocated by using this record rather than by reordering the network grid point array. The number of edges specified must equal the number of edges with boundary condition location points, figure 7.8. (For wake network type DW2 the single control point has default location on edge 1 by definition.) This record is not used for source (SA) and doublet (DA) analysis networks.

<EDGE CONTROL POINT LOCATIONS = <Type(s) = edge-number(s)>>
SNE, source-network-edge(s)
DNE, doublet-network-edge(s)

Parameter Defaults: Source or doublet edge control points have the default locations, figure 7.8. (Wake networks are doublet networks.)

Record Default: All edge control points have the default locations, figure 7.8.

Examples:

```
EDGE CONTROL POINT LOCATIONS = SNE = 1, 2, DNE = 1,2
EDGE = DNE = 2
```

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Record N13. Remove Doublet Edge Matching

This record specifies the no doublet strength matching along the edges of a doublet analysis network (type DA, figure 7.8), which is specified either through the boundary condition, record N9, or directly by record N11. Do not use this record for other types of doublet networks. This record suppresses any condition of doublet strength matching between abutting network edges or of zero doublet strength along a free edge; it is replaced by the network boundary condition. The no doublet strength matching condition allows a discontinuity in doublet strength either between network edges or along a free edge. To suppress doublet matching at an abutment of network edges, this record must be input for all edges (and possibly several networks) involved in the abutment.

< NO DOUBLET EDGE MATCHING = {{edge-number(s)}} >

Record Default: The doublet strength matching condition will be imposed at all edge control points.

Examples:

```
NO DOUBLET EDGE MATCHING = 2, 4
NO DOUB = 1
```

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Record sets N14 to N18 specify boundary condition equations and data associated with boundary condition equations. Each record set can appear anywhere after record set N2 within the given network data group. However, the records within each record set must be in the specified order. Each record set must begin with the identifying record. The subsequent records can be repeated several times, each time giving part of the total data. Each of these record sets is independent of the others; for example, the solutions list records (N14c, N15c, N16d, N17d and N18d) apply only to the record sets in which they appear. Examples are given at the end of each record set description.

For each boundary condition class, use of these record sets either are always required or may be required, the latter depending on the particular application, as listed below.

| Boundary Condition Class | Always Required | May Be Required |
|---|---|---|
| 1 | --- | N18 |
| 2 | N17 | N18 |
| 3 | N16 | N14,N17,N18 |
| 4 | --- | N14,N16,N17,N18 |
| 5 | N15 | N14,N16,N17,N18 |

Record sets which are not listed are not used for the indicated boundary condition class.

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This record set defines a closure edge boundary condition which is used in design applications, see section B.3.5. Only one closure condition can be specified for a network. The closure condition must replace a default boundary condition of (usually) source or (rarely) doublet strength matching on a network edge, which is the "specified edge" of the closure condition. (If the closure condition is specified to replace a doublet strength matching condition, the program may in some cases override the user specification and retain the doublet matching condition.)

The user can specify the closure condition in general form:

$$\iint_{\text{edge}}^{\text{edge}} [AU(\vec{w}_U \cdot \hat{n}) + AL(\vec{w}_L \cdot \hat{n}) + AA(\vec{w}_A \cdot \hat{n}) + AD\ \sigma\ ]\ ds = BC \qquad (7.4.1)$$

The perturbation mass flux is integrated over each column (or row) of panels which is headed by a control point on the "specified edge" of the network, the specified edge is also the lower integration limit. The integration covers the entire network. The left-hand side coefficients (AU, AL, AA and AD) are defined at every panel center point of the network. The right-hand side coefficient (BC) is defined for each row (or column) of panels and for each solution. The left-hand side coefficients must not be all null on any column (or row).

Ordering: The records within the record set must appear in the specified order. Record N14a, which identifies the record set, must appear first. Certain subsets can be repeated several times. The subset of records N14b to N14d can be repeated, each time specifying one term of the closure equation. The subset of records N14c and N14d can be repeated, each time specifying BC coefficients for one set of solutions.

Record N14a. Closure Edge Condition Identifier and Locator

This record identifies the closure edge condition record set, the "specified" network edge for the integral closure condition, and whether a source (SNE) or a doublet (DNE) matching condition on that edge is to be replaced by the closure condition. The network edge indexing scheme is illustrated in figure 7.3. The indicated network edge is also the lower limit of the closure integral: the integration is over the columns (or rows) of panels "normal" to that edge.

<CLOSURE EDGE CONDITION = {Type = edge-number}>
SNE, source-network-edge
DNE, doublet-network-edge

Record Default: No closure boundary condition for the network. Omit all records in the record set.

Restriction: The indicated source or doublet network edge must be one with boundary condition location points as determined by either the Boundary Condition Specified Record N9, see figures 7.4 to 7.6, or the Singularity Type Record N11 (figure 7.8), and by the Edge Control Point Locations Record N12.

Record N14b. Closure Term

This record identifies the (left or right-hand side) coefficient of the general closure equation (7.4.1). This and the subsequent records can be repeated, each time specifying numerical values for one coefficient. Unspecified coefficients = 0.

TERM = {Term}

"Term" has two characters (not separated) defined in table 7.5.

| Type of Term | First Character | Second Character |
|---|---|---|
| Coefficients of Normal Mass Flux (Left-Hand Side) | A | U (upper)<br>L (lower)<br>A (average)<br>D (difference) |
| Specified Total Normal Mass Flux (Right-Hand Side) | B | C |

Examples: TERM = AD, TERM = BC } see equation (7.4.1)

Table 7.5 Closure term identifications (record N14b)

Record N14c. Closure Solutions List

This record specifies the solutions corresponding to the subsequent numerical values. The record is input only for the right-hand side term, identifier BC in record N14b. (The left-hand side coefficients are independent of the solution.) This and the subsequent record can be repeated, each time specifying numerical values for one set of solutions.

<SOLUTIONS = {{solution-id(I)}}>

solution-id = either the alphanumeric name (SID, record G6) or the ordering index which identifies the solution

Record Default: All available solutions.

Record N14d. Closure Numerical Values

This record specifies numerical values at the panel center points of one term, defined by records N14b and N14c, of the general closure condition.

{{value(s)}}

The coefficient arrays can be either singly dimensioned (BC coefficients, right-hand side) or doubly dimensioned (AX coefficients, left-hand side). For the right-hand side coefficients, the index corresponds to the panel rows or columns, depending upon the integration direction (which is defined by the edge number specified in record N14a). For the left-hand side coefficients AX(I,J), the indices (I,J) are those of the rows and columns, respectively, of the panels; the indexing is independent of the integration direction.

The numerical values can be input in three general formats. Only one format can be used for each numerical values record. Alternate formats can be used if the term and solutions list records (N14b and N14c) are repeated. If several values are assigned to one point, the final value is that assigned by the latest record, that is, a later record supercedes an earlier record.

1. Global Value. A single numerical value is input. The program applies that value to the entire array.

2. Consecutive Ordering. The numerical values are specified for each panel center point in order: for the AX arrays this means all points on the first column in order of the rows, followed by all points on the second column in order of the rows, and so forth. Restriction: the entire array must be input, that is, numerical values must be input for either all panel center points (AX arrays) or all panel rows or columns (BC array).

3. Indexed Input. The index or indices and the corresponding values of the coefficients are input together. The possible formats and examples are given in table 7.6.

Example: Specify the closure condition

$$\iint_{\text{edge 1}}^{\text{edge 3}} AD \;\sigma\; ds = BC$$

which replaces a source matching condition on edge 1 where AD = 1. for all columns and for all rows except row 4 where AD = .5; where BC has the same value for all columns; and where BC = 0. for solution 1 and BC = 3. for solution 2.

```
CLOSURE EDGE CONDITION = SNE=1
 TERM = AD $ ( ALL , ALL ) = 1. $ ( 4 , ALL ) = .5
 TERM = BC
 SOLUTIONS = 1 $ 0.
 SOLUTIONS = 2 $ 3.
```

Indexed Input:

Numerical values of either one or two dimensional arrays can be specified at particular points. There are three possible formats for the input record, with the general form: a left-hand side giving the indices of the points, an equal sign, and a right-hand side giving the numerical value assigned to the point or points.

1. Format for Single Point. The left-hand side gives the index or indices of the single point to which the numerical value is assigned.

   Examples: ( 2 ) = value
   ( 1 , 4 ) = value

2. Format for Range of Indices. The left-hand side gives the range of indices of the points to which the numerical value is assigned. Rule: "3 TO 6" specifies indices 3 through 6.

   Examples: ( 4 TO 7 ) = value
   ( 2 , 4 TO 8 ) = value
   ( 1 TO 6 , 3 TO 10 ) = value

3. Format for Global Range of Indices. The left-hand side gives a global range of indices by using "ALL" or "MAX." Rule: "ALL" specifies the entire range of the index. Rule: "n TO MAX" specifies indices n through the maximum value.

   Examples: ( 3 TO MAX ) = value
   ( ALL , 8 ) = value
   ( 1 TO 3 , ALL ) = value
   ( ALL ) = value } value assigned
   ( ALL , ALL ) = value } to all points

General Rule: On the left-hand side, the four symbols ( , ) = and the three words TO, ALL and MAX must be preceded and followed by at least one blank.

Table 7.6 - Formats for indexed input, with examples

Record Set N15. Coefficients of General Boundary Condition Equation Record Set

This record set specifies the coefficients of a general (class 5) boundary condition equation, figure 7.9. Omit this record set for class 1, 2, 3 and 4 boundary conditions (record N9). Besides the coefficient terms, the user can specify tangent vector (record set N16) and specified flow (record set N17) terms in the boundary condition equations. In most cases two independent equations are required. The first and second equations correspond to the user-specified source and doublet singularity type arrays (record N11), respectively. These arrays determine the locations (record N15d) where the boundary condition equations are required. However, if a null singularity array NOS or NOD is specified, then the corresponding boundary condition equations must not be specified. Also, if a wake singularity array DW1 or DW2 is specified, the corresponding boundary condition equation is not specified. It is noted that PAN AIR may override a user-specified boundary condition equation at some control points, see appendix A.2 of the Theory Document.

Ordering: The records within the record set must appear in the specified order. Record N15a, which identifies the record set, must appear first. Certain subsets can be repeated several times. The subset of records N15b to N15e can be repeated, each time specifying one or more terms of the boundary condition equations. The subset of records N15c to N15e can be repeated, each time specifying a right-hand side coefficient for one set of solutions. The subset of records N15d to N15e can be repeated, each time specifying values at one type of control point location.

Record N15a. Coefficients of General Boundary Condition Equation Identifier

This record identifies the general boundary condition equation record set.

<COEFFICIENTS OF GENERAL BOUNDARY CONDITION EQUATION>

Record Default: Class 5 boundary conditions are not specified (record N9). Omit all records in the record set.

| boundary condition type | left-hand side | | right-hand side |
|---|---|---|---|
| mass flux analysis | $a_U(\tilde{w}_U \cdot \hat{n}) + a_L(\tilde{w}_L \cdot \hat{n})$<br>$a_A(\tilde{w}_A \cdot \hat{n}) + a_D\sigma$ | | $b_n\tilde{U}_o \cdot \hat{n}$ |
| potential | $c_U\phi_U + c_L\phi_L$<br>$c_A\phi_A + c_D\mu$ | | $b_p\tilde{U}_\infty \cdot \tilde{\psi}$ |
| velocity design | $\tilde{t}_U \cdot \tilde{v}_U + \tilde{t}_L \cdot \tilde{v}_L$<br>$\tilde{t}_A \cdot \tilde{v}_A + \tilde{t}_D \cdot \tilde{v}\mu$ | = | $b_t\tilde{t}_t \cdot \tilde{U}_o$ |
| velocity analysis | $e_U(\tilde{v}_U \cdot \hat{n}) + e_L(\tilde{v}_L \cdot \hat{n})$<br>$e_A(\tilde{v}_A \cdot \hat{n}) + e_D(\tilde{v}_D \cdot \hat{n})$ | | $\beta$ |

where

$\tilde{w}$ = perturbation mass flux
$\hat{n}$ = panel normal
$\tilde{t}$ = panel tangent
$\tilde{v}$ = perturbation velocity
$\phi$ = perturbation velocity potential
$\sigma$ = source strength
$\mu$ = doublet strength
$\beta$ = total specified flow
$\tilde{\psi} = (x/s\beta^2, y, z)$
$\tilde{U}_o$ = total onset flow
$\tilde{U}_\infty$ = uniform onset flow

subscripts:

U = upper
L = lower
A = average
D = difference
n = normal to panel
p = potential
t = tangent to panel

Figure 7.9 - General boundary condition equation

Record N15b. Equation Term

This record identifies the coefficient and the index of the general boundary condition equation, figure 7.9, which are specified in the subsequent numerical values. This and the subsequent records can be repeated, each time specifying numerical values for at least one coefficient. Unspecified coefficients = 0., except BT = -1. at all control points.

TERM = {Term}

"Term" has three characters (not separated) as defined in table 7.7.

| Type of Term | First Character | Second Character | Third Character |
|---|---|---|---|
| Left-hand side | A mass flux | U upper | 1 first equation |
| | C potential | L lower | 2 second equation |
| | E velocity | A average | |
| | | D difference | |
| Right-hand side | B general coefficient | N mass flux or velocity | |
| | | P potential | |
| | | T tangential velocity | |

Examples: TERM = AD1, TERM = BP2 } see coefficients in figure 7.9

Table 7.7 - General boundary equation term identifications (record N15b)

Record N15c. Equation Solutions List

This record specifies the solutions corresponding to the subsequent numerical values. This record is input only for the right-hand side terms, identifiers BX in record N15b. (The left-hand side coefficients are independent of the solution index.) This and the subsequent records can be repeated, each time specifying numerical values for one set of solutions.

< SOLUTIONS = {{solution-id(I)}} >

solution-id = either the alphanumeric name (SID, record G6) or the ordering index which identifies the solution

Record Default: All available solutions

Record N15d. Equation Control Point Locations

This record allows the user to specify different numerical values for the coefficients at different types of control point locations. This and the subsequent records can be repeated, each time specifying numerical values at one type of control point location.

POINTS = {Location}
ALL-CONTROL-POINTS
CENTER-CONTROL-POINTS
EDGE-CONTROL-POINTS
ADDITIONAL-CONTROL-POINTS

Restrictions: Values must be specified at all control points, since the program does not assign a default value to the control points after the TERM has been specified by record N15b. (The user can establish a default value by using the "POINTS=ALL" option.)

Record N15e. Equation Numerical Values

This record specifies the numerical values of the term-solution(s)-points, specified by records N15b to N15d, of the general boundary condition equation.

{{value(s)}}

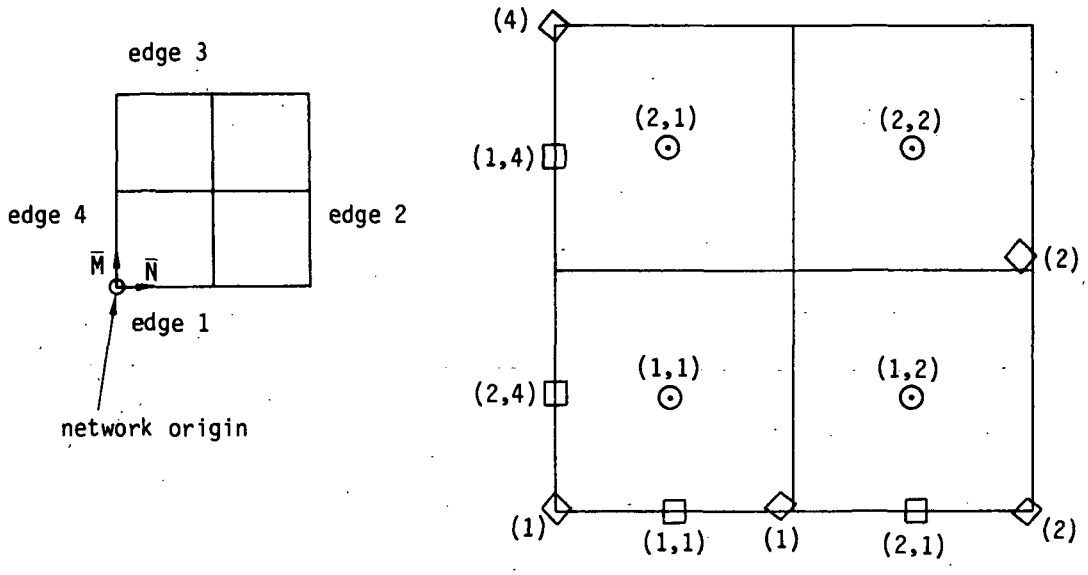
The type of control point location (record N15d) affects the indexing of the array of values. The indexing of both the control points and the corresponding arrays is described in figure 7.10.

The numerical values can be input in three general formats. Only one format can be used for each numerical values record. Alternate formats can be used if the control point locations record N15d is repeated. If several values are assigned to one point, the final value is that assigned by the latest record, that is, a later record supercedes an earlier record.

1. Global Value. A single numerical value is input. The program applies that value to all indicated control points.

2. Consecutive Ordering. The numerical values are input for each indicated control point in order: all points on the first column in order of the rows, followed by all points on the second column in order of the rows, and so forth. Restriction: the entire array must be input, that is, numerical values must be input for all indicated (by record N15d) control points.

3. Indexed Input. The indices and the corresponding values are specified together. The possible formats and examples are given in table 7.6. Restriction: this format cannot be used if the control point location type (record N15d) is ALL.




View of Upper Surface

⊙ CENTER control points

□ EDGE control points

◇ ADDITIONAL control points

CENTER control point array is VALUE(I,J) where I,J are the row, column indices.

EDGE control point array is VALUE(I,J) where I is the control point index and J is the edge index.

ADDITIONAL control points are corner control points and points added by the program as a result of network abutments; the array is VALUE(J) where J is the edge index. (The same value is assigned to all ADDITIONAL control points on the edge.)

ALL control points are the collection (in order) of CENTER, EDGE and ADDITIONAL control points.

Note: The VALUE (I,J) array is input in the order: VALUE(1,1), VALUE(2,1),..., VALUE(N,1), VALUE(1,2), VALUE(2,2),...

Figure 7.10 - Indexing system for arrays corresponding to the control point location options

Example: Boundary condition equations for class 1, subclass 3 (figure 7.4) and one solution, input as a class 5 boundary condition. The boundary condition equations are

(1) $\sigma = 0$

(2) $\vec{w}_A \cdot \hat{n} = -\vec{U}_o \cdot \hat{n}$

The mass flux analysis terms of the general boundary condition equation (figure 7.9) are

$$a_U(\vec{w}_U \cdot \hat{n}) + a_L(\vec{w}_L \cdot \hat{n}) + a_A(\vec{w}_A \cdot \hat{n}) + a_D\sigma = b_n\vec{U}_o \cdot \hat{n}$$

To get the boundary condition equation (1), the non-zero coefficients are

$a_D = 1.$

$b_n = 0.$ (default value)

The corresponding "Term" form (table 7.7) is

AD1 = 1.

BN1 = 0.

To get the boundary condition equation (2), the non-zero coefficients are

$a_A = 1.$

$b_n = -1.$

The corresponding "Term" form is

AA2 = 1.

BN2 = 1.

The input records to specify the boundary condition equations (at all control points) are:

```
COEFFICIENTS OF GENERAL EQUATION
  TERM = AD1 $ POINTS = ALL $ 1.
  TERM = BN1 $ POINTS = ALL $ 0.
  TERM = AA2 $ POINTS = ALL $ 1.
  TERM = BN2 $ POINTS = ALL $ -1.
```

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Record Set N16. Tangent Vectors for Design Record Set

This record set specifies tangent vector coefficients which appear in the general boundary condition equation, figure 7.9. Omit this record set for class 1 and 2 boundary conditions. The associated terms of the equation are

Left-hand side: $\vec{t}_U \cdot \vec{v}_U + \vec{t}_L \cdot \vec{v}_L + \vec{t}_A \cdot \vec{v}_A + \vec{t}_D \cdot \vec{\nabla}\mu$

Right-hand side: $b_t \vec{t}_t \cdot \vec{U}_o$

Tangent vector terms are required in design applications. Some left-hand side and right-hand side terms are required for class 3 boundary conditions, depending on the subclass. The tangent vector terms are zero unless defined otherwise in this record set. The boundary condition equations for design (class 3) and for general (classes 4 and 5) applications allow different values for the left and right-hand side tangent vectors. However the left and right-hand side vectors are equal in standard applications, see section B.3.3. If equal, several vectors (including those from both boundary condition equations) can be specified by the same numerical data by using the options in record N16b.

Ordering: The records within the record set must appear in the specified order. Record N16a, which identifies the record set, must appear first. Certain subsets can be repeated several times. The subset of records N16b to N16g can be repeated, each time specifying vector coefficients for one or more terms of the boundary condition equations. The subset of records N16d to N16g can be repeated, each time specifying a right-hand side vector coefficient for one set of solutions. The subset of records N16e to N16g can be repeated, each time specifying values at one type of control point location.

Record N16a. Tangent Vectors for Design Identifier

This record identifies the tangent vectors for design record set.

< TANGENT VECTORS FOR DESIGN >

Record Default: No tangent vector coefficients appear in the boundary condition equations for the network. Omit all records in the record set.

Record N16b. Tangent Vectors Term

This record identifies which tangent vectors of the general boundary condition equation, figure 7.9, are specified in the subsequent numerical values. The index of the boundary condition equation, that is, the first or the second equation, is also identified. This and the subsequent records can be repeated, each time specifying numerical values for one or more tangent vectors. Unspecified tangent vectors are zero.

TERM = {{Term(s)}}

"Term" has three characters (not separated) as defined in table 7.8.

Restriction: The right-hand side vectors (TERM = TTn) are multiplied by BT, whose value is specified in record N9 for class 4 boundary conditions and in record set N15 for class 5 boundary conditions. If both left and right-hand side vectors are specified by "Term(s)", then the right-hand side vectors must be the same for all solutions (record N16d).

| Type of Term | First Character | Second Character | Third Character |
|---|---|---|---|
| Left-hand Side | T | U upper<br>L lower<br>A average<br>D difference | 1 first equation<br>2 second equation |
| Right-hand Side | | T onset tangent | |

Examples: TERM = TA2 -- $\vec{t}_A$ in equation 2

TERM = TT1 -- $\vec{t}_{t1}$ in equation 1

Table 7.8 - Tangent vector term identifications (record N16b)

Record N16c. Tangent Vectors Scaling

This record suppresses the automatic program scaling of the input vector values into vectors with unit length.

<UNALTERED>

Record Default: Input vector values (record N16f) are scaled to unit length by the program.

Record N16d. Tangent Vectors Solutions List

This record specifies the solutions corresponding to the subsequent numerical values. This record is input only for the right-hand side tangent vectors (identifier TTn in record N16b). (The left-hand side vectors are independent of the solution index.) This and the subsequent records can be repeated, each time specifying numerical values of right-hand side tangent vectors for one set of solutions.

<SOLUTIONS = {{solution-id(I)}}>

solution-id = either the alphanumeric name (SID, record G6) or the ordering index which identifies the solution

Record Default: All available solutions

Record N16e. Tangent Vectors Control Point Locations

This record allows the user to specify different numerical values of the tangent vectors at different types of control point locations. This and the subsequent records can be repeated, each time specifying numerical values at one type of control point location.

POINTS = {Location}
ALL-CONTROL-POINTS
CENTER-CONTROL-POINTS
EDGE-CONTROL-POINTS
ADDITIONAL-CONTROL-POINTS

Restriction: Values must be specified at all control points, since the program does not assign a default value to the control points after the TERM has been specified by record N16b. (The user can establish a default value by using the "POINTS=ALL" option.)

Record N16f or Record N16g (not both) can be used to specify numerical values of tangent vectors for each location specified by record N16e.

Record N16f. Tangent Vectors Numerical Values

This record specifies numerical values of the three components of the tangent vectors defined by records N16b and N16d.

<{{ values }}>

The type of control point location (record N16e) affects the indexing of the array of values. This indexing of both the control points and the corresponding arrays is described in figure 7.10.

The numerical values (three components for each control point) can be input in three general formats. Only one format can be used for each numerical values record. Alternate formats can be used if the control point locations record N16e is repeated. If several values are assigned to one point, the final value is that assigned by the latest record, that is, a later record supercedes an earlier record.

1. Global Value. A single set of three numerical values is input. The program applies that set of values to all indicated control points.

2. Consecutive Ordering. The numerical values are specified for each indicated control point in order: all points on the first column in order of the rows, followed by all points on the second column in order of the rows, and so forth. Restriction: the entire array must be input, that is, numerical values must be input for all indicated (by record N16e) control points.
   Format: tvx(1,1), tvy(1,1), tvz(1,1),
   tvx(2,1), tvy(2,1), tvz(2,1), ...

3. Indexed Input. The indices and the corresponding values of the three vector components are specified together. The possible formats and examples (for a scalar quantity) are given in table 7.6. Restriction: this format cannot be used if the control point location type (record N16e) is ALL.

Restrictions: All three components of the tangent vectors are input, although this is redundant due to the tangency condition. The vectors are projected by the program onto the panel. If any vector input in record N16f is not within 60 of a subpanel plane, the program gives an error. The three components must not be separated; they either must be on the same card or record continuation must be indicated by a plus (+) as the last character on a card.

Record Default: Tangent vectors are not specified by this method.

Record N16g. Tangent Vectors Standard Numerical Values

This record is used if the tangent vectors have a standard form.

```
<Method>
COMPRESSIBILITY-DIRECTION
MID-POINT = {originating-edge-number}
            1  (from edge 1 to edge 3)
            2  (from edge 2 to edge 4)
            3  (from edge 3 to edge 1)
            4  (from edge 4 to edge 2)
```

For either option, a tangent vector of unit length is defined at all control points specified by record N16e. For the COMPRESSIBILITY-DIRECTION option the vectors are in the direction of the projection of the compressibility vector onto the panel. For the MID-POINT option the vectors are parallel to a line connecting the mid-points of the indicated edges.

Record Default: Tangent vectors are not specified by this method.

Example: Tangent vectors for class 3, subclass 1 (figure 7.6) boundary conditions for one solution. For all control points the (unit) vectors are the projection of the compressibility direction into the panel.

```
TANGENT VECTORS FOR DESIGN
TERM = TU1, TT1
POINTS = ALL
COMPRESSIBILITY-DIRECTION
```

Example: Tangent vectors for class 3, subclass 6 (figure 7.6) boundary conditions. For all solutions and all control points the vectors are equal, have unit magnitude and are in the direction of the $x_0$ axis.

```
TANGENT VECTORS
TERM = TU1, TT1, TL2, TT2
POINTS = ALL
1., 0., 0.
```

Record Set N17. Specified Flow Record Set

This record set defines specified flows which are the scalar quantities (β terms) on the right-hand side of the general boundary condition equation, figure 7.9. Omit this record set for class 1 boundary conditions. There can be two specified flow terms, one for each of the two boundary condition equations, at a control point. The specified flow terms are required for class 2 and 3 boundary conditions and may be required for class 4 and 5 boundary conditions. The specified flow terms are zero for all solutions and all control points, if record set N17 is not used.

Ordering: The records within the record set must appear in the specified order. Record N17a, which identifies the record set, must appear first. Certain subsets can be repeated several times. The subset of records N17b to N17f can be repeated, each time specifying values in one boundary condition equation. The subset of records N17c to N17f can be repeated, each time specifying values for different input/image part(s) of the total configuration. The subset of records N17d to N17f can be repeated, each time specifying values for one set of solutions. The subset of records N17e and N17f can be repeated, each time specifying values at one type of control point location.

Record N17a. Specified Flow Identifier

This record identifies the specified flow record set.

<SPECIFIED FLOW>

Record Default: All specified flow terms in the boundary condition equations are zero for the network. Omit all records in the record set.

Record N17b. Specified Flow Term

This record identifies the boundary condition equation (that is, the first or the second equation) for which specified flow values are defined in the subsequent numerical values. This and the subsequent records can be repeated to specify numerical values for the other boundary condition equation. Specified flow = 0. for an unspecified equation number.

TERM = {equation-number}
equation-number = 1 or 2

Record N17c. Specified Flow Symmetries

This record allows the user to define, either in combination or separately, the specified flows on the input network and/or its images. This and the subsequent records can be repeated, each time specifying values in another input or image region(s).

<INPUT-IMAGES = {{Image(s)}}>

INPUT
1ST
2ND
3RD

The meanings of the Image(s) terms are defined in figure 7.11. The meanings depend upon whether there are one to two planes of configuration symmetry defined in record G4.

Record Default: The defaults depend upon the flow symmetry specified in record G4. If no flow symmetry was specified, the record default is the INPUT option. If flow symmetry (or the ground effect option) was specified, then the record default is the INPUT option plus all images in plane(s) of flow symmetry.

Restriction: The specified image options must be consistent with any flow symmetry (or ground effect option) specified in record G4.

Record N17d. Specified Flow Solutions List

This record specifies the solutions corresponding to the subsequent numerical values for the specified flow. This and the subsequent records can be repeated, each time specifying values for one set of solutions.

<SOLUTIONS = {{solution-id(I)}}>

solution-id = either the alphanumeric name (SID, record G6) or the ordering index which identifies the solution

Record Default: All available solutions

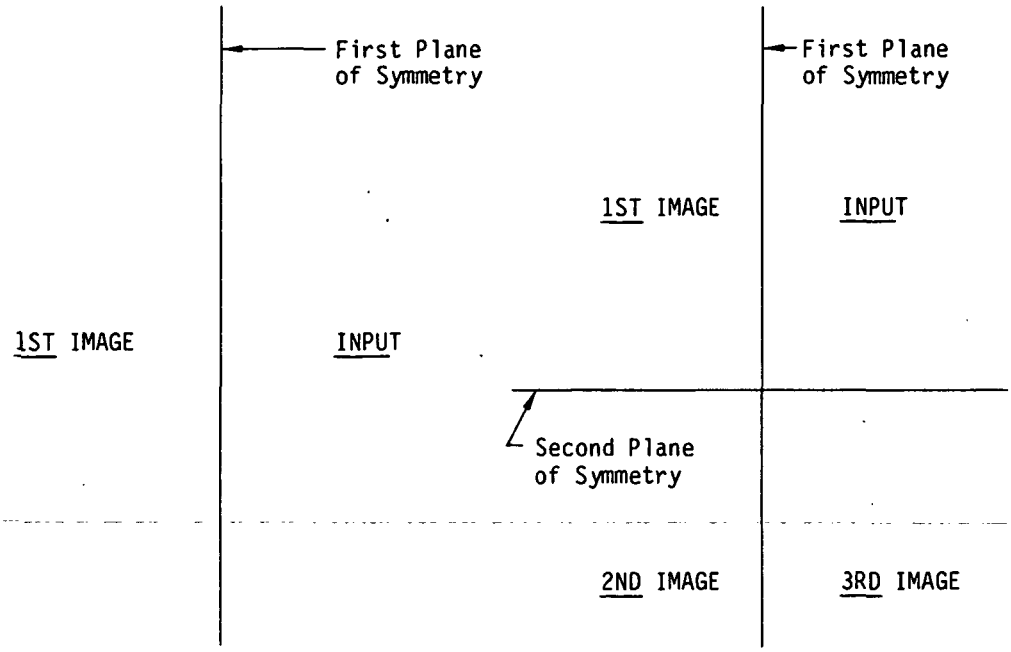


Figure 7.11 – Input-image identifications for one and two planes of configuration symmetry

Record N17e. Specified Flow Control Point Locations

This record allows the user to specify different numerical values of the specified flow at different types of control point locations. This and the subsequent records can be repeated, each time specifying numerical values at one type of control point location.

POINTS = {Location}
ALL-CONTROL POINTS
CENTER-CONTROL POINTS
EDGE-CONTROL POINTS
ADDITIONAL-CONTROL POINTS

Restrictions: Values must be specified at all control points, (1) since the program does not assign a default value to the control points after the TERM has been specified by record N17b, and (2) even if the specified flow data is not used at some of the control points. (The user can easily establish a default by using the "POINTS=ALL" option.)

Record N17f. Specified Flow Numerical Values

This record specifies the numerical values of the specified flows as defined by records N17b to N17e.

{{value(s)}}

The type of control point location (record N17e) affects the indexing of the array of values. The indexing of both the control points and the corresponding arrays is described in figure 7.10.

The numerical values can be input in three general formats. Only one format can be used for each numerical values record. Alternate formats can be used if the control point locations record N17e is repeated. If several values are assigned to one point, the final value is that assigned by the latest record, that is, a later record supercedes an earlier record.

1. Global Value. A single numerical values is input. The program applies that value to all indicated control points.

2. Consecutive Ordering. The numerical values are specified for each indicated control point in order: all points on the first column in order of the rows, followed by all points on the second column in order of the rows, and so forth. Restriction: the entire array must be input, that is, numerical values must be input for all indicated control points.

3. Indexed Input. The indices and the corresponding values are specified together. The possible formats and some examples are given in table 7.6. Restriction: this format cannot be used if the control point location type (record N17e) is ALL.

Example: Specified flows for class 2, subclass 5 (figure 7.5) boundary condition equations with two solutions and for a configuration with one plane of configuration symmetry, with asymmetric flow (record G4). For both solutions $\beta_1 = -.05$ for both input and image, and for all control points. For solution 1, $\beta_2 = +.01$ for both input and image, and for all control points. For solution 2, $\beta_2 = +.01$ for input, $\beta_2 = -.01$ for image, and for all control points.

```
SPECIFIED FLOW
 TERM=1
  INPUT-IMAGES=INPUT, 1ST
    POINTS = ALL $ -.05
 TERM=2
  INPUT-IMAGES=INPUT, 1ST
   SOLUTIONS=1
    POINTS=ALL $ +.01
  INPUT-IMAGES=INPUT
   SOLUTIONS=2
    POINTS=ALL $ +.01
  INPUT-IMAGES=1ST
   SOLUTIONS=2
    POINTS=ALL $ -.01
```

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Record Set N18. Local Onset Flow Record Set

This record set defines the local onset flow which appears in the right-hand side of the boundary condition equations and (optionally) in the computation of flow quantities such as the pressure coefficient and local Mach number. The total onset flow $\vec{U}_o$ is

$$\vec{U}_o = \vec{U}_\infty + \vec{U}_{rot} + \vec{U}_{loc}$$

The uniform $\vec{U}_\infty$ and rotational $\vec{U}_{rot}$ onset flows are defined for the entire configuration by record G6. The local onset flow is defined on a network by network basis. Since the local onset flow appears on the right-hand side of the boundary condition equations, it must be specified for each solution.

Ordering: The records within the record set must appear in the specified order. Record N18a, which identifies the record set, must appear first. Certain subsets can be repeated several times. The subset of records N18c to N18f can be repeated, each time specifying values for different input/image part(s) of the total configuration. The subset of records N18d to N18f can be repeated, each time specifying values for one set of solutions. The subset of records N18e and N18f can be repeated, each time specifying values at one type of control point location.

Record N18a. Local Onset Flow Identifier

This record identifies the local onset flow record set.

< LOCAL ONSET FLOW >

Record Default: All local onset flow terms are zero for the network. Omit all records in the record set.

Record N18b. Local Onset Flow Term

This record identifies one of two possible ways of specifying the numerical values of the local onset flow. All values must be specified in the same way for the network.

TERM = {Term}
ALPHA-BETA-MAGNITUDE
VXYZ

In the first option the three input numerical values are the angle of attack, angle of sideslip, and magnitude of the local onset flow velocity. (The angles are specified in the same manner as those defining the uniform onset flow velocity, that is, a rotation of $-\beta$ followed by a rotation of $-\alpha$, see figure 7.2 and section B.2.1. The angles are specified in degrees.) In the second option the three input numerical values are the three components of the local onset flow velocity (in the reference coordinate system).

Record N18c. Local Onset Flow Symmetries

This record allows the user to specify, either in combination or separately, the local onset flows on the input network and/or its images. This and the subsequent records can be repeated, each time specifying values in another input or image region(s).

<INPUT-IMAGES = {{Image(s)}}>
INPUT
1ST
2ND
3RD

The meanings of the Image(s) terms are defined in figure 7.11. The meanings depend upon whether there are one or two planes of configuration symmetry defined in records G4.

Record Default: The defaults depend upon the flow symmetry specified in record G4. If no flow symmetry was specified, the record default is the INPUT option. If flow symmetry (or the ground effect option) was specified, then the record default is the INPUT option plus all images in plane(s) of flow symmetry.

Restriction: The specified image options must be consistent with any flow symmetry (or ground effect option) specified in record G4.

Records N18d. Local Onset Flow Solutions List

This record specifies the solutions corresponding to the subsequent numerical values for the local onset flow. This and the subsequent records can be repeated, each time specifying values for one set of solutions.

<SOLUTIONS = {{solution-id(I)}}>

solution-id = either the alphanumeric name (SID, record G6) or the ordering index which identifies the solution

Record Default: All available solutions

Record N18e. Local Onset Flow Control Point Locations

This record allows the user to specify different numerical values of the local onset flow at different types of control point locations. This and the subsequent record can be repeated, each time specifying numerical values at one type of control point location.

POINTS = {Location}
ALL-CONTROL-POINTS
CENTER-CONTROL-POINTS
EDGE-CONTROL-POINTS
ADDITIONAL-CONTROL-POINTS

Restrictions: Values must be specified at all control points, (1) since the program does not assign a default value to the control points after the TERM has been specified by record N18b, and (2) even if the local onset flow velocity is not used at some of the control points. (The user can easily establish a default by using the "POINTS=ALL" option.)

Record N18f. Local Onset Flow Numerical Values

This record specifies the numerical values of the local onset flow. A set of three values is specified for each control point. The meaning of the three values was specified in record N18b.

{{values}}

The type of control point location (record N18e) affects the indexing of the array of values. The indexing of both the control points and the corresponding arrays is described in figure 7.10 (record N15e).

The numerical values (three for each control point) can be input in three general formats. Only one format can be used for each numerical values record. Alternate formats can be used if the control point locations record N18e is repeated. If several values are assigned to one point, the final value is that assigned by the latest record, that is, a later record supercedes an earlier record.

1. Global Value. A single set of three numerical values is input. The program applies that set of values to all indicated control points.

2. Consecutive Ordering. The numerical values are specified for each indicated control point in order: all points on the first column in order of the rows, followed by all points on the second column in order of the rows, and so forth. Restriction: the entire array must be input, that is, numerical values must be input for all indicated control points.

3. Indexed Input. The indices and the corresponding values are specified together. The possible formats and examples (for a scalar quantity) are given in table 7.6. Restriction: this format cannot be used if the control point location type (record N18e) is ALL.

Restrictions: The set of three values must not be separated. They either must be on the same card or record continuation must be indicated by a plus (+) as the last character on a card.

Example: Local onset flow $\alpha = \beta = 0$ for both input and image (one plane of symmetry), and for all control points, where $|\vec{U}_{loc}| = 1.$ for solution 1 and $|\vec{U}_{loc}| = 2.$ for solution 2.

```
LOCAL ONSET FLOW
TERM = ALPHA
 INPUT-IMAGES = INPUT, 1ST
  SOLUTIONS = 1
   POINTS = ALL $ 0.,0.,1.
  SOLUTIONS = 2
   POINTS = ALL $ 0.,0.,2.
```

## 7.5 Geometric Edge Matching Data Group

This data group allows the user to define abutments between two or more network edges. For network edges defined in an abutment, the default boundary condition is doublet strength matching between the abuting edges.

Abutments of network edges can be defined in either of two ways. First, PAN AIR has an automatic abutment procedure. Abutments are identified by the closeness of the network edges, using the geometric edge matching tolerance distance (record G7). The procedure is described in section B.3.5, also in appendix F of the *Theory Document*. The automatic procedure can be globally suppressed as described under record G7. Second, the user can specify abutments by using the present data group. In case of conflict, a user-specified abutment supercedes an automatically defined abutment.

Ordering: Record GE1, which identifes the data group, must appear first. The subgroup of records GE2 to GE4 can be repeated, each time specifying one abutment. For each subgroup, record GE2 must appear first.

Record GE1. Geometric Edge Matching Data Group Identifier

This record identifies the data group.

<BEGIN GEOMETRIC EDGE MATCHING DATA>

Record Default: No user-specified network edge abutments. Omit all records in the data group.

Records GE2 to GE4 specify an abutment of network edges. The records are repeated for each abutment set. The data for each set are independent.

Record GE2. Abutment Definition

This record specifies the networks and the whole or partial edges which form the abutment. The doublet strength matching boundary condition will be applied to those edges. This record must appear first in any abutment set.

< ABUTMENT {{ = network-id(I), edge number(I) < end-point-pair(I) / ENTIRE-EDGE > }} >

The combination of "network-id, edge-number, end-point-pair or ENTIRE-EDGE" is repeated for each network edge in the abutment. Each network-id must be preceded by an equal sign.

network-id = either the alphanumeric name (record N2a) or the ordering index, which identify the network, see discussion on record N2a.

edge-number = integer index (figure 7.3) of the network edge in the abutment.

end-point-pair = indices of the two panel corner points of the network edge segment which is to be in the abutment. (The points are ordered consecutively in the direction of increasing edge numbers, with the corner point having index 1.) The two points can be specified in either order.

The final parameter specifies whether an edge segment or the entire edge is included in the abutment. For the first network in the abutment the default is ENTIRE-EDGE. For subsequent networks the default results in the end-point-pair being selected to match the segment (or entire edge) specified for the first network.

Restrictions: A maximum of 5 edges, including edges in planes of symmetry, can be specified in one abutment. A single edge can be specified if it abuts its reflection(s) in plane(s) of symmetry. All data must be a single card; record continuation is indicated by a plus (+) as the last character on a card.

Example, see figure 7.12:

```
      ABUTMENT = A1,3,ENTIRE-EDGE +
               = A2,1,2,5         +
               = A3,1,ENTIRE-EDGE
```

Record GE3. Abutment in Planes of Symmetry

This record specifies whether an abutment occurs in one or two planes of configuration symmetry, defined by record G4.

< PLANE OF SYMMETRY = {Plane} >
FIRST-PLANE-OF-SYMMETRY
SECOND-PLANE-OF-SYMMETRY
BOTH-PLANES-OF-SYMMETRY

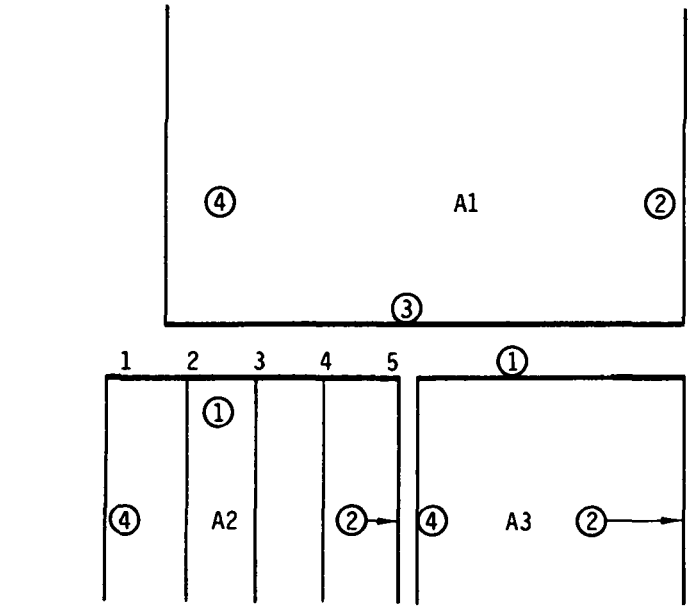
*Record Default: The abutment is not in plane(s) of symmetry.*

Record GE4. Smooth Edge Treatment Option

This record specifies smooth edge treatment (doublet strength matching by the spline functions) instead of the standard edge treatment (doublet strength matching by boundary condition). This option is restricted to abutments with only two edges, including possible plane(s) of symmetry. If the abutment contains more than two edges, the program will override the request for smooth edge treatment and will impose doublet strength matching through the boundary conditions (the standard method). This option is also restricted to networks (1) with singularity types (record N11) of doublet-analysis (DA) and either null-source (NOS) or source analysis (SA), (2) larger than 2 panels by 2 panels, and (3) with the same method of velocity computation (record N10) selected.

< SMOOTH EDGE TREATMENT >

Record Default: Standard edge treatment




○ edge number

Figure 7.12 - Example of a user-specified abutment (record GE2)

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## 7.6 Flow Properties Data Group

This data group specifies post-solution calculations, that is, those which occur after the singularity strengths have been determined from the solution of the composite boundary condition equation (A.3.5). The data group consists of two independent subgroups corresponding to the two program modules which calculate flow properties: surface flow properties subgroup (PDP module), and forces and moments subgroup (CDP module).

Independent calculation "cases" are specified in each subgroup. These are identified by alphanumeric case-id names. For each data subgroup, the program assigns a consecutive ordering index to each case. Subsequently, each case can be identified by its data subgroup and either by its (non-blank) case-id name or by its ordering index. A maximum of 100 cases is allowed for each subgroup.

The flow properties calculations can be specified in all types of update runs, which are described in section 7.2.3. In an update run, the user may or may not want to retain the flow properties calculations cases specified in a previous run. Two options are available for this in record FP1.

Each subgroup repeats some options and data for which default values were defined in the global data group (records G8 to G14), see table 7.3. This allows the definition of different options and data for each case in each subgroup. Upon completion of a case, the program returns to the original default values.

Ordering: The first record in the flow properties data group must be the group identifier, record FP1. This is followed by the two subgroups, which can appear in either order.

Record FP1. Flow Properties Data Group Identifier

This record identifies the data group and must be the first record in the data group. An update option is specified which instructs the DIP module on how to treat any instructions for flow properties calculations which exist on the DIP data base.

<BEGIN FLOW PROPERTIES DATA = <Update-option>>
NEW
REPLACE
UPDATE

Parameter Default: NEW

NEW: Either an originating run or an update run with no post-solution cases from a previous run.

REPLACE: Existing data for post-solution cases are eliminated. New cases are defined.

UPDATE: Existing data for post-solution cases (identified by their case-id names or ordering indices) are retained, but can be selectively updated. New cases can be added.

Record Default: No flow properties calculations. Omit all records in data group.

### 7.6.1 Surface Flow Properties Data Subgroup

This data subgroup specifies cases of calculation of flow properties at points on a user-specified configuration, which can be composed of any combination of wake and non-wake networks. The user also selects from the set of solutions (record G6) for each case of surface flow properties calculations. Multiple, independent surface flow properties cases can be specified. For each case the first record must be the subgroup identifier, record SF1. The other records can appear in any order.

Record SF1. Surface Flow Properties Data Subgroup Identifier

This record identifies the data subgroup and the optional case-id name.

<SURFACE FLOW PROPERTIES = <case-id>>

The "case-id" is an alphanumeric name (maximum of 20 characters, without imbedded blanks) which is used for identification in the output and in subsequent data processing. The case-id name must be unique (or blank) within the data subgroup.

Record Default: No surface flow properties calculations. Omit all records in data subgroup.

Examples:

```
SURFACE FLOW PROPERTIES = CASE-1
SURF FLOW = OUTBOARD-WING-CASE3
```

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Record SF2. Networks and Images Selection

This record specifies the configuration on which flow properties are to be calculated. The configuration can be formed from any combination of the previously defined networks and their images. An option for an orientation change is included.

<NETWORKS-IMAGES {{= network-id(I) <Images(I)> <Orientation(I)>}}>

| | Images(I) | Orientation(I) |
|---|---|---|
| | INPUT | RETAIN |
| | 1ST | REVERSE |
| | 2ND | |
| | 3RD | |

Parameter Defaults: INPUT and RETAIN

The combination of "network-id, Images, Orientation" is repeated for each network. Each network-id must be preceded by an equal sign.

network-id = either the alphanumeric name (record N2a) or the ordering index which identify the network, see discussion on record N2a.

Images = The possible options depend on the number of planes of symmetry. More than one option can be selected. The options are identified in figure 7.11.

Orientation = The REVERSE option reverses the direction of the panel normal vectors, and thus reverses the definition of the network upper and lower surfaces (for the present case of surface flow properties calculations).

Record Default: All defined non-wake networks with all distinct images and with no orientation change. (All distinct images: input network and all image network(s) across plane(s) of symmetry for which the asymmetric-flow option was specified in record G4.)

Restrictions: Wake network(s) can be specified only if the wake flow properties were tagged (record N6) for the network(s). All data must be on a single record; record continuation is indicated by a plus (+) as the last character on a card.

Examples:

```
NETWORK-IMAGES = WING-A, INPUT, 1ST +
               = WING-B, REVERSE    +
               = WING-C, 1ST
NETW = BODY-1 = BODY-2 = BODY-3
```

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Record SF3. Solutions List

This record identifies the solutions for which surface flow properties are to be calculated.

<SOLUTIONS = {{solution-id(I)}}>

solution-id = either the alphanumeric name (SID, record G6) or the ordering index which indentifies the solution.

Record Default: All available solutions

Examples:

```
SOLUTIONS = 1,3,5
SOLU = 2  4
```

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Record Set SF4. Calculation Point Locations Record Set

This record set is used to specify the points at which flow properties calculations are to be made. The two records must be in the indicated order.

Record SF4a. Point Types

In this record the user specifies the types of points at which the calculations are to be made, including arbitrary user-specified points.

<POINTS = {{Location(s) / GRID-POINTS}}>
ALL-CONTROL-POINTS
CENTER-CONTROL-POINTS
EDGE-CONTROL-POINTS
ADDITIONAL-CONTROL-POINTS
ARBITRARY-POINTS

GRID points are the network enriched grid (panel corner points, center points and edge mid-points). ALL control points consist of CENTER, EDGE and ADDITIONAL control points. ADDITIONAL control points are network corner control points and any edge control points added by the program as a result of network abutments, see section B.3.4. ARBITRARY points are specified by the user; this option is an instruction to read the next record.

Record Default: CENTER-CONTROL-POINTS only

Record SF4b. Arbitrary Points

Omit this record if the ARBITRARY-POINTS option was not specified in the previous record. This record specifies the locations (panel, network, and coordinates) of the user-specified points.

< {{ panel-row, panel-column, network-id, {{ x(I), y(I), z(I) }} }} >

panel-row = row index of the panel containing the point(s)
panel-column = column index of the panel containing the point(s)
network-id = either the alphanumeric name (record N2a) or the ordering index which identify the network (see discussion on record N2a) containing the point(s)
x(I), y(I), z(I) = coordinates of the arbitrary point(s)

This record can be repeated for each panel. The network must be one of those specified in record SF2. The panel row and column indexing scheme is shown in figure 3.2 and B.3. The point coordinates are in the reference coordinate system. The coordinates are given for the INPUT network, even if that option is not selected in record SF2. The PDP module will project the specified point into the indicated panel. A warning will be printed if the projected point is not in the indicated panel.

Record Default: No user-specified arbitrary points.

Restrictions: Each record (which starts with the "panel-row") must be a single record; record continuation is indicated by a plus (+) as the last character on a card. A maximum of 10 points can be specified on a record; to specify more than 10 points on a panel, use new record(s).

Example:

```
POINTS = CENTER, ARBITRARY
1,1, WING-A, 1.2  2.5  0., 1.3  2.5  0., +
  1.4  2.5  0.
2, 1, WING-A, 1.5  2.5  0.
1, 2, WING-B, 2.1  7.5  0.
```

Records SF5 to SF9 are repetitions of records in the Global Data Group. The global values defined there can be changed for each case in the Surface Flow Properties Data Subgroup. Records SF5 to SF9 allow selection of several options for the calculation of flow velocities and pressure coefficients. The calculations will be made for all combinations of the selected options. Care should be used in selecting the number of options, since the use of all options can result in a large amount of output.

Record SF5 (and record G8). Surface Selection Options

These options specify the network surfaces or surface combinations for which flow properties are to be calculated. See discussion on record G8. Note that the network upper and lower surfaces are originally defined by the input network geometry (record N2b). However if the REVERSE option (record SF2) is used for a network, then the selection of options in the present record must be based on the reversed surface definition. Several options can be selected, resulting in multiple calculations.

< SURFACE SELECTION = {{ Surface(s) / UPPER / LOWER / UPLO (upper minus lower) / LOUP (lower minus upper) / AVERAGE }} >

Record Default: Option(s) selected in Global Data Group

Record SF6 (and record G9). Selection of Velocity Computation Method

This record selects the velocity computation method(s). See section B.4.1 and see discussion on record G9. Both options can be selected, resulting in multiple calculations.

< SELECTION OF VELOCITY COMPUTATION = {{ Method(s)}} >
BOUNDARY-CONDITION
VIC-LAMBDA

Restrictions: The VIC-LAMBDA method can be used only if the velocity influence coefficient matrix was stored for every network specified in record SF2, either by record N3 for non-wake networks or by records N3 and N6 for wake networks. (Alternately, use of record G15 is equivalent to use of record N3 for every network.)

Record Default: Option(s) selected in Global Data Group

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Record SF7 (and record G10). Computation Option for Pressures

This record selects a preferred direction, which is required by several relations used to compute pressure coefficients and local Mach numbers. See section B.4.2 and see discussion on record G10. The option does not change the velocities, but does change some of the pressure coefficients calculated in the PDP module.

| | |
|---|---|
| <COMPUTATION OPTION FOR PRESSURES = | {Option}> |
| | UNIFORM-ONSET-FLOW |
| | TOTAL-ONSET-FLOW |
| | COMPRESSIBILITY-VECTOR |

Record Default: Option selected in Global Data Group.

Restrictions: See discussion on record G10. The local onset flow will be zero unless it was stored: either globally (record G16) or for each network (record N4).

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Record SF8 (and record G13). Ratio of Specific Heats

This record specifies values of the ratio of specific heats, which is used in the SA1 velocity correction (records SF10b and SF11b) and in both the pressure coefficient and local Mach number relations. See discussion on record G13. A set of values can be specified, one for each solution (in order) selected in record SF3.

< RATIO OF SPECIFIC HEATS = {{gamma(s)}} >

Record Default: The set of values assigned to the solutions in Global Data Group.

**Page intentionally left blank**

Record SF9 (and record G14). Reference Velocity for Pressure

This record is used only if UINF is zero in record G6. (Otherwise UINF is the pressure reference velocity.) This record specifies values of the reference velocity used in calculation of the pressure coefficients. See discussion on record G14. A set of values can be specified, one for each solution (in order) selected in record SF3.

<REFERENCE VELOCITY FOR PRESSURE = {{rvp(s)}}>

Record Default: The set of values assigned to the solutions in Global Data Group.

**Page intentionally left blank**

Record sets SF10 and SF11 specify options for the printout and the data base creation. The records also specify calculation options related to the velocities and pressure coefficients. Different sets of these calculation options can be specified for the printout and the data base.

Record Set SF10. Printout Options Record Set

This record set specifies printout options and two calculation options defining the quantities to be printed. The three records in the record set must appear in the order given below.

Record SF10a. Printout Options

This record specifies the printout options for the PDP program module.

```
<PRINTOUT =    <Option(s)>>
                 Integers or Keywords, listed in table 7.9
                 ALL (all allowable options)
```

Parameter Defaults: Non-wake networks: 1, 4, 6, 9, 13
Wake networks: 1, 2, 4, 9, 13, 14, 15

The options are listed in table 7.9. Option 15 is meaningless for non-wake networks; if selected, the values output will be zero.

Record Default: No data printout. Omit next two records (SF10b and SF10c).

| DIP Index | DIP Keyword | PDP Headings | Quantity |
|---|---|---|---|
| 1 | POINT | ROW | Point, row index |
| | | COL | Point, column index |
| 2 | XYZ | X-CORD | Point, x-coordinate |
| | | Y-CORD | Point, y-coordinate |
| | | Z-CORD | Point, z-coordinate |
| 3 | PWXYZ | PWX | Perturbation mass flux, x-component |
| | | PWY | Perturbation mass flux, y-component |
| | | PWZ | Perturbation mass flux, z-component |
| 4 | WXYZ | WX | Total mass flux, x-component |
| | | WY | Total mass flux, y-component |
| | | WZ | Total mass flux, z-component |
| 5 | WMAG | WMAG | Total mass flux, magnitude |
| 6 | WN | WN | Total mass flux, normal component |
| 7 | PVXYZ | PVX | Perturbation velocity, x-component |
| | | PVY | Perturbation velocity, y-component |
| | | PVZ | Perturbation velocity, z-component |
| 8 | VXYZ | VX | Total velocity, x-component |
| | | VY | Total velocity, y-component |
| | | VZ | Total velocity, z-component |
| 9 | VMAG | VMAG | Total velocity, magnitude |
| 10 | PHI | PHI | Perturbation potential |
| 11 | PHIT | PHIT | Total potential |
| 12 | ML | MLISEN | Local Mach number, isentropic |
| | | MLLINE | Local Mach number, linear |
| | | MLSECO | Local Mach number, second-order |
| | | MLREDU | Local Mach number, reduced second-order |
| | | MLSLEN | Local Mach number, slender body |
| 13 | CP | CPISEN | Pressure coefficient, isentropic |
| | | CPLINE | Pressure coefficient, linear |
| | | CPSECO | Pressure coefficient, second-order |
| | | CPREDU | Pressure coefficient, reduced second-order |
| | | CPSLEN | Pressure coefficient, slender body |
| 14 | GMUXYZ | GMUX | Doublet strength gradient, x-component |
| | | GMUY | Doublet strength gradient, y-component |
| | | GMUZ | Doublet strength gradient, z-component |
| 15 | PSI | PSI | Angle, average total velocity and surface vorticity (degrees) |
| 16 | SING | SINGS | Singularity strength, source |
| | | SINGD | Singularity strength, doublet |
| 17 | SPDMAX | SPDMAX | Maximum total speed |
| 18 | SPDCRT | SPDCRT | Critical speed |
| 19 | CPVAC | CPVAC | Pressure coefficient, vacuum |

(x,y,z) = reference coordinate system

Note: If option 13 (CP) is selected and Mach number (record G5) is less than one, then critical pressure coefficients (figure B.48) are also output.

Table 7.9 - PRINTOUT and DATA BASE options for surface flow properties data subgroup (records SF10a and SF11a)

Record SF10b (and record G11). Velocity Correction Options

This record specifies possible velocity corrections. See section B.4.1 and see discussion on record G11. Several options can be selected, resulting in multiple calculations.

<VELOCITY CORRECTIONS = {{Correction(s)}}>
NONE
SA1
SA2

Record Default: Option(s) selected in Global Data Group.

Record SF10c (and record G12). Pressure Coefficient Rules

This record specifies the rules to be used to calculate the pressure coefficients and local Mach numbers. See discussion on record G12. This record can be omitted if neither option 12 nor 13 (nor ALL) were selected in record SF10a. Several rules can be selected, resulting in multiple calculations.

<PRESSURE COEFFICIENT RULES = {{Rule(s)}}>
ISENTROPIC
LINEAR
SECOND-ORDER
REDUCED-SECOND-ORDER
SLENDER-BODY

Record Default: Option(s) selected in Global Data Group

Example for Record Set SF10:

```
PRINTOUT
VELOCITY CORRECTIONS = SA1
PRESSURE COEFFICIENT RULES = LINEAR, SECOND-ORDER
```

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Record Set SF11. Data Base Options Record Set

This record set specifies data base creation options and two calculation options defining the quantities to be stored on the data base. The PDP data base can subsequently be sorted, in the PPP module, into a form suitable for printing and plotting. The three records in the record set must appear in the order given below.

Record SF11a. Data Base Options

This record specifies the data base options for the PDP program module.

<DATA BASE = <Option(s)>>
Integers or Keywords, listed in table 7.9.
ALL (all allowable options)

Parameter Defaults: Non-wake networks: 1, 4, 6, 9, 13
Wake networks: 1, 2, 4, 9, 13, 14, 15

The options are listed in table 7.9. Option 15 is meaningless for non-wake networks; if selected, the values output will be zero.

Record Default: No PDP data base is created. Omit the next two records (SF11b and SF11c).

Record SF11b (and record G11). Velocity Correction Options

This record specifies possible velocity corrections. See section B.4.1 and see discussion on record G11. Several options can be selected, resulting in multiple calculations.

<VELOCITY CORRECTIONS = {{Correction(s)}}>
NONE
SA1
SA2

Record Default: Option(s) selected in Global Data Group

Record SF11c (and record G12). Pressure Coefficient Rules

This record specifies the rules to be used to calculate the pressure coefficients and local Mach numbers. See discussion on record G12. This record can be omitted if neither option 12 nor 13 (nor ALL) were selected in record SF11a. Several rules can be selected, resulting in multiple calculations.

<PRESSURE COEFFICIENT RULES = {{Rule(s)}>
ISENTROPIC
LINEAR
SECOND-ORDER
REDUCED-SECOND-ORDER
SLENDER-BODY

Record Default: Option(s) selected in Global Data Group

Example for Record Set SF11:

```
DATA = ALL
VELO = NONE, SA2
PRES = ISENTROPIC, LINEAR, SECOND-ORDER
```

7.6.2 (Reserved)

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### 7.6.3 Forces and Moments Data Subgroup

This data subgroup specifies the calculation of force and moment coefficients for user-specified cases composed of one or more networks. Several methods can be used for the calculation of the velocities and pressure coefficients. The force and moment coefficients are obtained by integration of the pressure coefficients together with the momentum transfer term over each network surface, with the option for including the contributions obtained from a special edge force calculation. The force and moment coefficients can be calculated for individual panels, for columns of panels, for networks, and for the case CONFIGURATION. (The CONFIGURATION is defined as the INPUT networks and all images across planes of configuration symmetry, except planes with the ground-effect option specified in record G4; see record FM8). The force and moment coefficients are calculated in the reference coordinate system and can also be expressed in the stability and wind axis systems and in a body axis system specified by the user.

In addition to the results for each independent case, the user has the option of adding the CONFIGURATION coefficients for each case into a total "accumulation case" to obtain the coefficients for the total vehicle. The accumulation case is output after the regular user-specified cases, with the case-id name "ACCUMULATION-CASE" and with integer index N, where N is one more than the integer index on the last user-specified case.

The coefficients for the accumulation case are the sum of the CONFIGURATION coefficients of the cases for which the accumulation option (record FM21) is specified. The accumulation case includes images across all planes of configuration symmetry, except planes with the ground effect option, as specified in record G4.

Ordering: The forces and moments data subgroup has two parts. The first part (records FM1 to FM6) defines global options and data. The second part (records FM7 to FM21) defines data for one case. The records in the second part are repeated for each case, with each case independent of the others. The records in the first part must appear before the records in the second part. The records within the each part may appear in any order except for the identifier records: record FM1 must be the first record in the first part and record FM7 must be the first record in the second part.

Record FM1. Forces and Moments Subgroup Identifier

This record identifies the data subgroup.

<FORCES AND MOMENTS>

Record Default: No forces and moments calculations. Omit all records in the data subgroup.

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Record FM2. Reference Parameters

This record defines one area and two length reference parameters. The first two parameters can subsequently be changed locally (by record FM11) for each case of forces and moments calculations. Use of the reference parameters is described in section B.4.3. (CR is used to nondimensionalize MY and BR is used to nondimensionalize MX and MZ, where these moment components are in the reference coordinate system.)

<REFERENCE PARAMETERS = {{Parameter, value}}>
SR
CR
BR

SR = area reference parameter; default value = 1.
CR = chord reference parameter; default value = 1.
BR = span reference parameter; default value = 1.

Record Default: All three parameters have their default values.

Examples:
REFERENCE PARAMETERS = CR, 5.
REFE = SR, 10., BR, 5.

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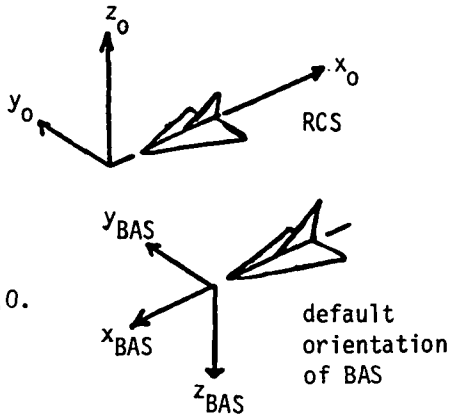
Record FM3. Axis Systems

This record specifies the axis systems in which the force and moment coefficients are to be calculated. (To a limited extent, the user can select from this set in subsequent records defining program output. However all desired axis systems must be specified in the present record.) The force and moment coefficients can be calculated in the reference coordinate system and in the stability, wind and body axis systems as requested by the user. The axis systems are described in section B.4.3. The stability and wind axis systems are solution-dependent. (The solutions are selected in record FM4.) The body axis system is defined by the user. In addition, the user defines the moment reference point for each axis system.

```
<AXIS SYSTEMS =   {{List, <values>}>
                    RCS   <mrp>
      Parameter Defaults:   0.,0.,0.
                    SAS   <mrp>
      Parameter Defaults:   RCS values
                    WAS   <mrp>
      Parameter Defaults:   RCS values
                    BAS   <Euler angles <mrp>>
      Parameter Defaults:   180.,0.,180., 0.,0.,0.
```




RCS = reference coordinate system
SAS = stability axis system
WAS = wind axis system
BAS = body axis system
*mrp = coordinates (in the RCS) of the moment reference point*
Euler angles = Euler angles (in degrees) defining the BAS by three rotations from the RCS, see section B.4.3.

Record Default: AXIS SYSTEMS = RCS, 0.,0.,0., WAS, 0.,0.,0.

Examples:

```
AXIS SYSTEMS = RCS, 100.,0.,0.
AXIS = RCS, 200.,0.,0.,  BAS
```

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Record FM4. Solutions List

This record identifies the solutions for which force and moment coefficients are to be calculated.

<SOLUTIONS = {{solution-id(I)}}>

solution-id = either the alphanumeric name (SID, record G6) or the ordering index which identifies the solution

Record Default: All available solutions

Example:
SOLUTIONS = ALPHA-1, ALPHA-4

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Record FM5. Printout Options

This record specifies global printout options for the force and moment coefficients. The global options can subsequently be changed locally (by record FM19) for each case.

<PRINTOUT = {{Parameter(s)}}>

"Parameter" can select either one general option or several specific options.

General Parameter Options:
- NO: no data printed
- SAME: same options as specified for DATA BASE (record FM6)
- ALL: all available specific options listed below

Specific Parameter Options:

| | | |
|---|---|---|
| PANELS | Selected-axis-system(s)<br>RCS: Default Parameter<br>SAS<br>WAS<br>BAS | see record FM3 |
| COLSUM | Selected-axis-system(s)<br>RCS: Default Parameter<br>SAS<br>WAS<br>BAS | see record FM3 |
| NETWORK | | |
| CONFIGURATION | | |

PANELS: print panel force and moment coefficients
COLSUM: print column sums of panel force and moment coefficients
NETWORK: print force and moment coefficients for each network
CONFIGURATION: print force and moment coefficients for the configuration; see record FM8 for a description of how the configuration is defined.

The user can select the axis system(s) for the PANELS and COLSUM options. The selected axis systems must be specified in record FM3. For the NETWORK and CONFIGURATION options, the program uses all axis systems specified in record FM3. (The PANELS option should be used with care: in most cases this option will be the dominant contributor to the printed output.)

Restriction: The SAME option can not be specified for both the printout and the data base (records FM5 and FM6).

Record Default: PRINTOUT = COLSUM,RCS, NETWORK, CONFIGURATION

Examples:

```
PRINTOUT = ALL
PRIN = PANELS, COLS,RCS,WAS, NETW, CONF
```

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Record FM6. Data Base Options

This record specifies global data base creation options for the force and moment coefficients. The global options can subsequently be changed locally (by record FM20) for each case. The CDP data base can subsequently be sorted, in the PPP module, into a form suitable for printing and plotting.

< DATA BASE = {{Parameter(s)}} >

The "Parameter" options are identical to those of record FM5, with the obvious interchange of the printout and data base creation functions.

Record Default: DATA = COLSUM,RCS, NETWORK, CONFIGURATION

Examples:

```
DATA BASE = SAME
DATA = COLS,RCS,WAS,NETW,CONF
```

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Records FM7 to FM21 specify one case of force and moment coefficients calculations on a specified configuration. This part of the data subgroup can be repeated, with each case independent of the others. The default options and parameter values specified in the Global Data Group (records G8 to G14) and in records FM2, FM5 and FM6 can be redefined for each case.

The accumulation option allows the addition of the force and moment coefficients of each case (which may represent portions of the entire configuration) to obtain total values for the entire configuration. The "accumulation" force and moment coefficients are obtained in all specified coordinate systems (record FM3) but for only one set of calculation options (records FM12 to FM16), see record FM21.

Ordering: Record FM7 must be the first record for each case, that is, for this part of the data subgroup. The other records can appear in any order.

Record FM7. Case Identifier

This record identifies a case of forces and moments calculations.

CASE = <case-id>

The "case-id" is an alphanumeric name (maximum of 20 characters, without imbedded blanks) which is used for identification in the output and in subsequent data processing. The case-id name must be unique (or blank) within the forces and moments data subgroup.

Example:
CASE = FORCES-WING-3B

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Record FM8. Networks and Images Selection

This record specifies the networks and their images on which the force and moment coefficients are to be calculated. This can be any combination of the previously defined networks and their images, and includes a possible orientation change. A computation option involving the momentum transfer term is also specified.

<NETWORKS-IMAGES{{ = network-id(I) <Images(I)><Orientation(I)><FM-Option(I)>}>

| Images(I) | Orientation(I) | FM-Option(I) |
|---|---|---|
| INPUT | RETAIN | PRESSURE-ONLY |
| 1ST | REVERSE | MOMENTUM-TRANSFER |
| 2ND | | |
| 3RD | | |

Parameter Defaults: RETAIN and PRESSURE-ONLY. For Images, the parameter default is all "distinct" images, see Record Default description below.

The combination of "network-id, Images, Orientation, FM-Option" is repeated for each network. Each network-id must be preceded by an equal sign.

network-id = either the alphanumeric name (record N2a) or the ordering index which identify the network, see discussion on record N2a.

Images = The options are identified in figure 7.11. The possible options depend on the number of planes of symmetry. More than one option can be selected.

Orientation = The REVERSE option reverses the definition of the network upper and lower surfaces for the present case of forces and moments calculations.

FM-Option = The MOMENTUM-TRANSFER option results in the momentum transfer term being included in the force and moment coefficients, see section B.4.3. If the option is not selected, then that term is omitted, which is the PRESSURE-ONLY option. Only one option can be selected.

Record Default: All defined non-wake networks, with all distinct images, with no orientation change and without the momentum transfer term. (All distinct images: input network and all image(s) across plane(s) of configuration symmetry for which the asymmetric-flow option was specified in record G4. Thus, images across planes with symmetric flow are not distinct images.)

Limitation: The Images option applies to the panels, column-sum and network force and moment coefficients (as specified in records FM19 and FM20). The configuration force and moment coefficients include the INPUT and all images across planes of configuration symmetry, except planes with the ground effect option, as specified in record G4; this is true irrespective of what Image options are specified.

Restrictions: Wake network(s) can be specified only if the wake flow properties were tagged (record N6) for the network(s). All data must be on a single record; record continuation is indicated by a plus (+) as the last character on a card.

Examples:

```
    NETWORK-IMAGES = WING-A, INPUT, 1ST +
                   = WING-B, REVERSE    +
                   = WING-C, 1ST
    NETW = BODY-1  = BODY-2 = BODY-3
```

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Record FM9. Edge Force Calculation

This record specifies the edge force calculation on selected network edges, see section B.4.3. This calculation is appropriate for edges of thin configurations. The user should not specify both the edge force calculation and a velocity correction (record FM15). The edge force can be calculated only for networks for which the velocity influence coefficients have been stored, that is, the Store Velocity Influence Coefficient Matrix option was specified either globally (record G15) or individually (record N3) for each network specified in the present record.

< EDGE FORCE CALCULATION {{ = network-id(I), edge-number(s)}}>

The combination of "network-id, edge-number(s)" is repeated for each network with an edge force calculation on one or more edges. Each network-id must be preceded by an equal sign. The "network-id" is either the alphanumeric name (record N2a) or the ordering index which identify the network. The network edge numbering scheme is identified in figure 7.3.

Restrictions: Each specified network must also be specified in record FM8. All data must be on a single record; record continuation is indicated by a plus (+) as the last character on a card.

Record Default: No edge force calculation

Examples:

```
EDGE FORCE CALCULATION = WING-A, 3
EDGE =WING-1, 3 = WING-2, 3, 4
```

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Record FM10. Moment Axis

This record specifies the additional calculation of the moment about a user-specified axis, see section B.4.3. This capability can be used to calculate hinge moments, for example. The resulting moment must be interpreted carefully since the moment components in the reference coordinate system are nondimensionalized separately by the span (record FM2) and chord (record FM11) reference parameters.

<MOMENT AXIS = {x(1),y(1),z(1),x(2),y(2),z(2)}>

Record Default: No additional moment calculation

Example:
MOMENT AXIS = 0., 0., 0., 5., 10., 1.

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Record FM11. Local Reference Parameters

This record allows the redefinition, for each case, of the area and chord reference parameters defined in record FM2. This option should be used with care when a case is to be added into the accumulation case (using record FM21): the user must be sure that the accumulation case is the sum of individual cases with the same reference parameters.

$$< \underline{\text{LOCAL}}\ \underline{\text{REFERENCE}}\ \text{PARAMETERS} = \left\{\left\{ \begin{matrix} \text{Parameter, value} \\ \underline{\text{SR}} \\ \underline{\text{CR}} \end{matrix} \right\}\right\} >$$

SR = area reference parameter; default value defined by record FM2
CR = chord reference parameter; default value defined by record FM2

Record Default: Both parameters have the values defined by record FM2.

Examples:

```
LOCAL REFERENCE PARAMETERS = SR, 50.
LOCA REFE = SR,200., CR,20.
```

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Records FM12 to FM18 are repetitions of records in the Global Data Group. The global values defined there can be changed for each case in the Forces and Moments Data Subgroup. Records FM12 to FM18 allow selection of several options for the calculation of flow velocities and pressure coefficients. The calculations will be made for all combinations of the selected options. Care should be used in selecting the number of options, since the use of all options can result in a large amount of data output.

Record FM12 (and record G8). Surface Selection Option

This option specifies the network surface or surface combination for which force and moment coefficients are to be calculated. See discussion on record G8. Note that the network upper and lower surfaces are originally defined by the input network geometry (record N2b). However, if the REVERSE option (record FM8) is used for a network, then the selection of an option in the present record must be based on the reversed surface definition.

<SURFACE SELECTION = {Surface}>
UPPER
LOWER
UPLO (upper plus lower)
LOUP (lower plus upper)
AVERAGE (program replaces by LOUP)

The calculations of the force and moment coefficients have three basic options: UPPER, LOWER and UPLO. The UPLO option gives the coefficients for the total force and moment on the element, which is the quantity of physical interest. LOUP is equivalent to UPLO, see section B.4.3. AVERAGE is physically meaningless and is replaced by LOUP in the program.

| Restriction: Only one option can be selected. |
|---|

Record Default: Option (if only one) selected in Global Data Group

Record FM13 (and record G9). Selection of Velocity Computation Method

This record selects the method of velocity computation. See section B.4.1 and see discussion on record G9. Both options can be selected, resulting in multiple calculations.

< SELECTION OF VELOCITY COMPUTATION = {{ Method(s) }} >
BOUNDARY-CONDITION
VIC-LAMBDA

Restrictions: The VIC-LAMBDA method can be used only if the velocity influence coefficient matrix was calculated and stored for every network of the configuration specified in record FM8, either by record N3 for non-wake networks or by records N3 and N6 for wake networks. (Alternately, use of record G15 is equivalent to use of record N3 for every network.)

Record Default: Option(s) selected in Global Data Group

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Record FM14 (and record G10). Computation Option for Pressures

This record selects a preferred direction, which is required by several relations used to compute pressure coefficients. See section B.4.2 and see discussion on record G10.

<COMPUTATION OPTION FOR PRESSURES = {Option}>
UNIFORM-ONSET-FLOW
TOTAL-ONSET-FLOW
COMPRESSIBILITY-VECTOR

Record Default: Option selected in Global Data Group.

Restrictions: See discussion on record G10. The local onset flow will be zero unless it was stored: either globally (record G16) or for each network (record N4).

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Record FM15 (and record G11). Velocity Correction Options

This record specifies possible velocity corrections. See section B.4.1 and see discussion on record G11. Several options can be selected, resulting in multiple calculations.

< VELOCITY CORRECTIONS = {{Correction(s)}}>
NONE
SA1
SA2

Record Default: Option(s) selected in Global Data Group

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Record FM16 (and record G12). Pressure Coefficient Rules

This record specifies the rules to be used to calculate the pressure coefficients. See discussion on record G12. Several options can be selected, resulting in multiple calculations.

<PRESSURE COEFFICIENT RULES = {{Rule(s)}}>
ISENTROPIC
LINEAR
SECOND-ORDER
REDUCED-SECOND-ORDER
SLENDER-BODY

Record Default: Option(s) selected in Global Data Group.

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Record FM17 (and record G13). Ratio of Specific Heats

This record specifies values of the ratio of specific heats, which is used in the SA1 velocity correction (record FM15) and the pressure coefficient relations. See discussion on record G13. A set of values can be specified, one for each solution (in order) selected in record FM4.

< RATIO OF SPECIFIC HEATS = {{ gamma(s)}} >

Record Default: The set of values assigned to the solutions in Global Data Group.

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Record FM18 (and record G14). Reference Velocity for Pressure

This record is used only if UINF is zero in record G6. (Otherwise UINF is the pressure reference velocity.) This record specifies values of the reference velocity used in calculation of the pressure coefficients. See discussion on record G14. A set of values can be specified, one for each solution (in order) selected in record FM4.

<REFERENCE VELOCITY FOR PRESSURE = {{rvp(s)}}>

Record Default: The set of values assigned to the solutions in Global Data Group.

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Records FM19 and FM20 specify output options which for individual cases override the globally specified options (records FM5 and FM6).

Record FM19. Local Printout Options

This record specifies printout options for individual cases. Global options were specified in record FM5.

<LOCAL PRINTOUT = {{Parameter(s)}}>

"Parameter" can select either one general option or several specific options.

General Parameter Options:
- NO: no data printed
- SAME: same options as specified for DATA BASE (record FM20)
- ALL: all available specific options listed below

Specific Parameter Options:

| | | |
|---|---|---|
| PANELS | Selected-axis-system(s)<br>RCS: Default Parameter<br>SAS<br>WAS<br>BAS | see record FM3 |
| COLSUM | Selected-axis-system(s)<br>RCS: Default Parameter<br>SAS<br>WAS<br>BAS | see record FM3 |
| NETWORK | | |
| CONFIGURATION | | |

PANELS: print panel force and moment coefficients
COLSUM: print column sums of panel force and moment coefficients
NETWORK: print force and moment coefficients for each network
CONFIGURATION: print force and moment coefficients for the configuration, see record FM8 for a description of how the configuration is selected.

The user can select the axis system(s) for the PANELS and COLSUM options. The selected axis systems must be specified in record FM3. For the NETWORK and CONFIGURATION options, the program uses all axis systems specified in record FM3. (The PANELS option should be used with care; in most cases this option will be the dominant contributor to the printed output.)

Restrictions: The SAME and NO options cannot be specified for both the printout and the data base.

Record Default: Option(s) specified in record FM5

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Record FM20. Local Data Base Options

This record specifies data base creation options for individual cases. Global options were specified in record FM6.

< LOCAL DATA BASE = {{Parameter(s)}} >

The "Parameter" options are identical to those of record FM19, with the obvious interchange of the printout and data base creation functions.

Record Default: Option(s) specified in record FM6

Examples:

```
LOCAL DATA BASE = SAME
LOCA DATA = PANELS, COLS,RCS,WAS, NETW, CONF
```

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Record FM21. Accumulation Options

This record specifies the addition of the configuration force and moment coefficients of the present case to the accumulation case. Omit this record if the present case is not to be added to the accumulation total. This option allows the calculation of force and moment coefficients on an entire configuration. The total force and moment coefficients are obtained in all specified coordinate systems (record FM3). However, they are obtained for only one set of the calculation options of records FM13, FM15 and FM16. That set of calculation options is also specified by the present record.

<ACCUMULATE = <Option(I)>>

Option (1), Selection of Velocity Computation Method from record FM13 (and record G9), one only:

BOUNDARY-CONDITION
VIC-LAMBDA

Option (2), Velocity Correction Options from record FM15 (and record G11), one only:

NONE
SA1
SA2

Option (3), Pressure Coefficient Rules from record FM16 (and record G12), one only:

ISENTROPIC
LINEAR
SECOND-ORDER
REDUCED-SECOND-ORDER
SLENDER-BODY

Parameter Defaults: If Option(I) is omitted, the program will check the option(s) specified in the indicated record: if a single option was specified, that option is the parameter default; if more than one option was specified, the program gives an error.

Record Default: The configuration force and moment coefficients for the present case will not be added to the total force and moment coefficients of the accumulation case.

Example:

```
ACCUMULATE = VIC-LAMBDA, ISENTROPIC
ACCU = BOUN, SA1, LINE
```

## 7.7 Print-Plot Data Group

This data group specifies options for creation of data files in the Print-Plot Processor (PPP) module. These files can be used to print or plot output from several PAN AIR modules, see section 8.8. Three types of print-plot files can be created by the PPP module: network and panel geometry (from DQG data base), surface flow properties (from PDP data base), and force and moment coefficient data (from CDP data base). All data bases must be from the *current (originating or update) run only.*

Ordering: The first record must be the group identifier, record PP1. The other records are grouped into three record sets which can appear in any order. Within each record set the records must appear in the indicated order, since the records within a set can be repeated several times.

Restrictions: The specified data, for example, cases, solutions and networks, must be consistent with those specified for the earlier modules and available on the appropriate data base.

Update Options: Only one set of data can be specified for each of the three types of print-plot files. If a new set of input records is specified in an update run, the new set will replace any previous set on the DIP data base.

Record PP1. Print-Plot Data Group Identifier

This record identifies the data group.

<BEGIN PRINT PLOT DATA>

Record Default: No files will be created by the Print-Plot Processor (PPP) module. Omit all records in the data group.

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Record Set PP2. Geometry Data Record Set

This record set specifies creation of print-plot files for the panel corner point geometry (obtained from the DQG data base) for the specified networks. The two records in the set must appear in the indicated order.

Record PP2a. Geometry Data Identifier

This record identifies the geometry data record set.

<GEOMETRY DATA>

Record Default: No print-plot files created for geometry data. Omit all records in this set.

Record PP2b. Network Selection

This record specifies the networks for which geometry print-plot files are to be created.

<NETWORKS = {{network-id(I)}}>

network-id = either the alphanumeric name (record N2a) or the ordering index which identifies the network, see discussion on record N2a.

Record Default: All active networks on the DQG data base.

Example, record set PP2:

```
GEOMETRY DATA
 NETWORKS = WING-A, WING-B, +
            WING-C
```

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Record Set PP3. Point Data Record Set

This record set specifies creation of print-plot files for the flow properties calculated at points on the network surfaces. This record set corresponds to the calculations specified in the surface flow properties data subgroup and performed in the PDP module. The contents of the PDP data base are specified by record set SF11 for each case. A selection of cases, solutions, networks, and the type of point arrays can be made in the present input data. The data from all computation options originally specified (records SF5 to SF7, SF11b and SF11c) will be processed; no selection from these options is made in the PPP module.

The data on the print-plot files are assembled as a rectangular matrix. The matrix rows correspond to an array of network points which is either a column or a row of either control points or grid points (see record PP3e). The matrix columns correspond to the data base contents specified by records SF11a and SF11c (also see table 7.9).

Ordering: The records within the record set must appear in the specified order. Record PP3a, which identifies the record set, must appear first. Certain subsets can be repeated several times. Records PP3b to PP3e can be repeated, each time specifying options for one set of PDP cases. Records PP3c to PP3e can be repeated, each time selecting from the set of solutions specified in record SF3. Records PP3d to PP3e can be repeated, each time selecting from the set of the networks (and images) specified in record SF2. Record PP3e can be repeated to specify different types of point arrays.

Record PP3a. Point Data Identifier

This record identifies the point data record set.

<POINT DATA>

Record Default: No print-plot files created for point data. Omit all records in this set.

Record PP3b. Case Selection

This record specifies the cases for which print-plot files are to be created for point data.

<CASES = {{case-id(I)}}>

case-id = either the alphanumeric name (record SF1) or the ordering index which identify the PDP case

Record Default: All available cases

Record PP3c. Solutions List

This record specifies the solutions for which print-plot files are to be created for point data.

<SOLUTIONS = {{solution-id(I)}}>

solution-id = either the alphanumeric name (SID, record G6) or the ordering index which identifies the solution

Record Default: All available solutions

Record PP3d. Networks and Images Selection

This record specifies the networks and their images for which print-plot files are to be created for point data.

<NETWORKS-IMAGES {{= network-id(I) <Images(I)>}}>

Images: INPUT, 1ST, 2ND, 3RD

network-id = either the alphanumeric name (record N2a) or the ordering index which identifies the network. Each network-id must be preceded by an equal sign.

Images = The options are identified in figure 7.11. The possible options depend on the number of planes symmetry. More than one option can be selected.

Parameter Default: INPUT only

Record Default: All active networks and images on the PDP data base.

Record PP3e. Array Type

This record specifies the type of point arrays for the print-plot file. The resulting point arrays will be generated for either COLUMNS or ROWS of either CONTROL-POINTS or GRID-POINTS.

< ARRAY = < COLUMNS / ROWS > < CONTROL-POINTS / GRID-POINTS >>

Parameter Defaults: COLUMNS. The default for CONTROL-POINTS/GRID-POINTS depends upon the options selected for the PDP calculations. If only one point type was selected in record SF4a, then that type will be automatically selected as the present option. If both CONTROL-POINTS (at least the panel center control points) and GRID-POINTS were selected in record SF4a, then the default is CONTROL-POINTS.

Record Default: Both parameter defaults

Example, record set PP3:

```
POINT DATA
CASES = PDP-CASE-1
SOLUTIONS = 2, 3, 4
NETWORKS-IMAGES = FLAP-A1=FLAP-A2+
                = FLAP-A3
CASES = PDP-CASE-2
NETWORKS-IMAGES = OUTBOARD-WING, INPUT, 1ST
ARRAY = GRID-POINTS
```

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Record Set PP4. Configuration Data Record Set

This record set specifies creation of print-plot files for the force and moment coefficients on elements of the configuration. This record set corresponds to the calculations specified in the forces and moments data subgroup and performed in the CDP module. A selection of cases, solutions and network-images can be made in the present input data. The force and moment coefficients for all axis systems (record FM2), for all computation options (records FM12 to FM16) and for all surface elements (record FM6 or FM20) originally specified will be processed; no selection from these options is made in the PPP module. The term surface element here means panels, column-sums of panels, networks, configurations (all networks defined for one case), and any accumulated configurations (record FM21, total configuration defined by several cases).

The data on the print-plot files are assembled as a rectangular matrix. The matrix rows correspond to the specified set of solutions. The matrix columns contain two types of data. The first type is solution data: solution ordering index, ALPHA, BETA, UINF and WM (record G6). The second type is consists of the six force and moment coefficient components for all selected pressure coefficient rules (record FM16), and for all selected axis systems (records FM3 and FM20).

Ordering: The records within the record set must appear in the specified order. Record PP4a, which identifies the record set, must appear first. Certain subsets can be repeated several times. Records PP4b to PP4d can be repeated, each time specifying options for one set of cases. Records PP4c and PP4d can be repeated, each time specifying options for one set of solutions.

Record PP4a. Configuration Data Identifier

This record identifies the configuration data record set.

<CONFIGURATION DATA>

Record Default: No print-plot files created for configuration data. Omit all records in this set.

Record PP4b. Case Selection

This record specifies the cases for which print-plot files are to be created for configuration data.

<CASES = {{case-id(I)}}>

case-id = either the alphanumeric name (record FM7) or the ordering index which identifies the CDP case

Record Default: All available cases

Record PP4c. Solutions List

This record specifies the solutions to be included in the print-plot files.

<SOLUTIONS = {{solution-id(I)}}>

solution-id = either the alphanumeric name (SID, record G6) or the ordering index which identifies the solution

Record Default: All available solutions

Record PP4d. Networks and Images Selection

The PPP module handles the contents of the CDP data base by either of two methods. The first method is the default with the present record omitted: force and moment coefficients for all available surface elements are sorted and written onto the print-plot file. The data base contents were specified by record FM20 (or record FM6). This may result in many data sets on the print-plot file, particularly if force and moment coefficients on individual panels are included. The second method restricts the surface elements to those specified in the present record plus the case-configurations and any defined accumulation-configurations.

< NETWORKS-IMAGES {{ = network-id(I) <Images(I)> <PANELS><COLSUM> }} >

Images(I): INPUT | 1ST | 2ND | 3RD

network-id = either the alphanumeric name (record N2a) or the ordering index which identifies the network. Each network-id must be preceded by an equal sign.

Images = The options are identified in figure 7.11. The possible options depend on the number of planes of symmetry. More than one option can be selected.

PANELS: include panel force and moment coefficients

COLSUM: include column sums of panel force and moment coefficients

Parameter Default: INPUT only

The network-id and images must correspond to those originally specified in record FM8. The force and moment coefficients for the COLSUM (column-sum) and the PANELS will be put on the print-plot file if those options are selected here and were selected in record FM20 (or record FM6) for inclusion in the CDP data base.

Record Default: All surface elements on the CDP data base (for the cases specified in record PP4b).

Example, record set PP4:

```
CONFIGURATION DATA
CASES = FM-CASE-1, FM-CASE-2
SOLUTIONS = 2,4,6
NETWORKS-IMAGES = WING-A, COLSUM +
                = WING-B, INPUT, 1ST
```

## 8.0 System Output Data

PAN AIR modules produce output in the form of print files, permanent and temporary database files, plot files generated by the PPP module and the control card file generated by MEC (see section 6). This section of the User's Manual is a guide to the user for the interpretation of the output produced by PAN AIR modules. Section 8.1 discusses the printed output produced by each of the PAN AIR modules. Section 8.2 briefly summarizes the data on the database files. More detailed information concerning the contents of the database files will be found in the PAN AIR Maintenance Manual. Section 8.3 briefly discusses the plot files produced by PPP. Section 8.4 discusses the use and analysis of the CHECK DATA run. Section 8.5 discusses the control card files which are created by the MEC module when EXECUTION DIRECTIVES are provided.

### 8.1 Printed Output

The regular printed output is discussed below for each module in the PAN AIR system. Section 8.1.11 discusses error and warning messages which might occur during execution and which are due to some user error. All printed output from PAN AIR modules begins and ends with a label block which gives the module name and version and also provides the date and time of execution. In the end block the total execution time required to run the module is also printed.

After the beginning block a summary of the database file names and identifiers which the module will use or create is printed by all modules except MEC. Modules which are constructed in overlays also print the elapsed CPU time in seconds required to execute the overlay before the next overlay is called.

#### 8.1.1 MEC Output

The printed output consists of the input card data, the generated control cards for a PAN AIR run, error diagnostic data if input errors occur and the printed output image of the MEC temporary data base description. Examples of the output data from the MEC module for the PAN AIR run are given in figure 8.1.

The first page of the MEC output identifies the module and version which is executing and provides the date and time of execution. Following this is a reflection of the user input MEC directives. Each separate card is a single record of input (no continuation capabilities are provided in MEC) and is indexed sequentially by both a record count and a card count. Errors occuring in the input directives are diagnosed and printed.

If execution directives are provided, the next series of pages list the control cards which are generated on the MECCC file. After the control cards are listed, MEC prints the data base information tables for the permanent and temporary data bases to be used by the subsequent modules for the user

specified PAN AIR run. These tables contain the default and actual (user specified) names and locations (setname of disk unit, user account number or identification, etc.) of the PAN AIR data bases and the corresponding master definition files. This information is also stored in temporary MEC data base so that the subsequent modules can access the appropriate existing data bases or create a data base with the user specified name, location and password using the appropriate master definition file.

Subsequent pages contain the actual name of the database files. Immediately below the actual name is listed the name of the master definition file of the database. In the succeeding columns appear the file identifiers and set names (if required), the password (not used in the current version of PAN AIR), and an indication as to whether the database is a permanent one or a temporary one. The final three columns indicate whether the databases exist (labelled by 1), or not (labelled by 0), whether they are used by the problem which has been posed and whether the files are to be saved following solution of the problem. (Note that some databases are labelled as existing in the case of an update run.)

Part of the output created by the MEC module is a file name, MECCC which contains the control cards necessary to execute the appropriate sequence of the PAN AIR modules to accomplish the task the user has requested through the use of MEC directives. Section 6 of this document discusses the use of these directives. Section 8.5 contains a description of this control card procedure file produced by MEC.

### 8.1.2 DIP Output

There are three classes of output that are provided by DIP. They are: an echo of the input data; a data summary; and warning or error messages. The user may select any or all of these through the use of the CHECKOUT PRINTS command to DIP (see section 7.3, discussion on record G17).

Figure 8.2 illustrates the output from DIP when all options are selected. The echo of input data is mostly self-explanatory. Each successive card is numbered at the far right of the page. Each successive record of input is numbered at the left hand side of the page. Note that comments inserted in the input data count as a card but not as a record. Thus the record index and the card index of an input data item are not necessarily identical. A data summary is provided for the global data and for the network data. The global summary consists of the Mach number, direction of compressibility vector, symmetry information for both the configuration and the flow, a list of solutions describing the name associated with each solution and the relevant data, angle of attack and sideslip, magnitude of onset flow and direction and magnitude of rotational onset flow contributions. The summary of network data consists of a list of networks defining the network names, status (NEW, REPLACED or UPDATED), information concerning the boundary condition class and subclass for the network, the source and doublet singularity types of the network (abbreviations for the singularity types are described in table 8.1) and the number of corner point rows and columns in the network. In the case of class 4 boundary conditions the two "subclasses" are listed, one defining the index of the terms present in the left hand side of the boundary condition equation and the other defining the index of the terms present in the right

hand side of the equation. For an interpretation of the indexing of boundary condition classes and subclasses, see section 7.4, figures 7.4 to 7.7 and the examples of record N9.

### 8.1.3 DQG Output

The user may request, through DQG, a number of output items, most of which describe the geometry of the problem. These items include, warning messages, network corner point coordinates, network enriched grid coordinates, empty space abutments, all abutments, control point data and boundary condition data.

The type and amount of output provided by DQG depends on user requests through the CHECKOUT PRINTS command in the DIP input (see section 7.3 concerning record G17). The minimal DQG printed output will contain fatal error messages if errors occur, certain warning messages for highly irregular conditions and the CPU cost of execution of each overlay in DQG, printed just before the execution of the next overlay is begun.

The warning and error message output is discussed in section 8.1.11. Figure 8.3 illustrates the output from DQG when all options are requested by the user. The first page of output from DQG indicates the version of DQG, date and time of execution and describes the names and identifiers of the database files in use. This is followed by a listing of the network corner point coordinates. The row and column indices of each corner point are listed followed by its x, y and z coordinates in the reference coordinate system (RCS). If a network edge is collapsed (see section 7.4, record N2b of this document and the PAN AIR Theory Document, section D.1.4), the corner point coordinates are flagged by "CHANGED" in the last column of the listing even if their values are not redefined by the program.

After printing the network corner point coordinates the enriched grid point coordinates of the network are printed. The fine grid row and column indices of each corner point is listed followed by the corner point index number and the x, y and z coordinates in the Reference Coordinate System. Figures 8.4 and 8.5 illustrate the indexing scheme of the corner point rows and columns in the network (the coarse grid lattice indexing scheme) and the indexing scheme of the enriched grid (or fine grid) rows and columns in the network (the fine grid lattice indexing scheme).

Following the listing of the corner point data DQG describes the abutments in the configuration. First the abutments of network edges with one another or with planes of symmetry are listed. Then abutments with empty space are listed. Both output formats are similar. For each abutment, first the index of the abutment the abutment type and the number of networks in the abutment are printed. Abutments are indexed sequentially in the order they are defined by the user and in the order in which they are discovered by the automatic abutment search. There are three types of abutments: NON-SMOOTH, SMOOTH and EMPTY-SPC. These refer to the methods by which doublet strength will be made continuous across the network edge. In the case of NON-SMOOTH abutments, doublet matching boundary conditions will be imposed at control points along the edge of one of the networks in the abutment (see PAN AIR Theory Document, sections 5.3 and F). A SMOOTH abutment establishes doublet continuity by computing doublet splines which extend across network boundaries. In this

case both singularity parameters and control points along the edges of the networks are ignored in the computation of the solution (see PAN AIR Theory Document, section I.1). Empty space abutments are labelled by EMPTY-SPC. They occur wherever a network edge does not meet any other network edges or planes of symmetry. Except for non-matching edges of design networks and wake networks, boundary conditions are added along these empty space edges which force doublet strength to zero (see PAN AIR Theory Document, section F).

Below the general information about the abutment is a table describing the network edge(s) which make up the abutment. In the leftmost column is listed the network index and in the rightmost column is the network name. (Networks are indexed sequentially as they are read by DIP.) Note that a negative index indicates a plane of symmetry by convention. Thus -1 is the first plane of symmetry and -2 is the second plane of symmetry. Following this is the edge index of the network edge. In the next two columns are listed a description of the starting and ending points of the abutment. (Note that in PAN AIR a single abutment does not have to extend along the whole edge of a network. See the PAN AIR Theory Document, section 5.3 and F.) They are described in two fashions. First an integer is given which is the index of the corner point along the edge in a counter clockwise sense. (See figure 8.6). This is the form the user provides to DIP. After the integer there appear two integers enclosed in parantheses. These are the coarse grid row and column indices of the point. (DQG uses the coarse grid indexing system to describe abutments internally.)

After the description of the network edges which take part in the abutment, there appears a series of columns which describe at which edge and corner points in the abutment doublet or source matching boundary conditions are imposed. This group of columns are labelled "MATCHING DATA" and contain subcolumn headings of "START", "EDGE" and "END", indicating the control point at the starting corner points, the control points at edge midpoints between the starting corner point and the ending corner point, and the control point at the ending corner point of the network edges which make up the abutment. For each network edge in the table there are two rows. One is labelled "DOUBLET" and the other is labelled "SOURCE". An "M" in any location in the table indicates the control points at that location will be used to impose matching boundary conditions across the abutment. An "NM" indicates no matching condition is imposed at the point(s). Note that the imposition of a matching boundary condition at an empty space abutment is equivalent to setting the singularity strength at that point to zero.

Below the abutment description there appears a comment indicating whether gap filling panels have been added to this abutment (see PAN AIR Theory Document, section F.6).

The next major item in the DQG output is the DQG global data summary. In this section the RUN, PROBLEM and USER identifiers are printed followed by some global configuration data. The global configuration data define whether the run is an initial run or an update run (INIT or UPDA), and lists the Mach number, the compressibility vector, the total number of singularity parameters and control points, the number of non-null boundary conditions and the number of gap filling panels in the problem. Note that typically the number of singularity parameters, control points and boundary conditions will not be identical to one another. The number of non-null boundary conditions is the same as the size of the AIC matrix (including both known and unknown portions;

see PAN AIR Theory Document, section 5.7). The number of singularity parameters will equal the number of non-null boundary conditions unless there are null singularity parameters in the problem, such as at a collapsed edge of a network or along network edges which form a smooth abutment. The number of control points is included for completeness mostly and indicates in a rough sense the complexity of the problem. There may be more control points than the number of non-null boundary conditions or there may be fewer, depending on the detailed properties of the configuration. After this information is printed, there follows a description of the planes of symmetry if any are defined for the problem.

Following the summary of general properties of the problem there appears a summary of properties of the networks which make up the configuration. The network index and identifier are printed followed by a flag indicating updatability of the network, the number of corner point columns and rows in the network, the source and doublet type and the source and doublet edge types of the network. Note that if the network as a whole or any of its edges have been labelled as updatable the network is listed as being updatable in the table. The abbreviations indicating source or doublet type of the network are shown in table 8.2. Table 8.2 defines the meanings of the abbreviations used in the source and doublet edge type definitions. Note that source edge types are defined only for Source Design networks (see section 7.4, records N11 and N12, and figure 7.8; and the PAN AIR Theory Document, sections 5.4 and D).

After the DQG global data summary the control point data is printed. Note that this can be a large volume of printed output since data for ten control points requires a complete page. The control point data is printed for each network in succession. Within each network the data is printed first for all control points located at panel center points, then for all control points located at edge midpoints along the network edges and finally for all control points located at corner points of the network.

Data printed for each control point consists of the control point index, the fine grid row and column indices of the point, the (hypothetical) coordinates of the control point in the reference coordinate system, the normal vector at the control point and the characterizations of the control point for all symmetrizations and for each boundary condition. (Note that the hypothetical coordinate of the control point is different than the control point location printed in the PDP output. PDP prints the recessed coordinate of the control point. In the MAG module, wherever potential or velocity at a control point is computed, the recessed location of the control point is used to avoid a logarithmic singularity in the integral. The hypothetical location is used in MAG to compute matching boundary conditions and values of source and doublet strength. (See PAN AIR Theory Document, section 5.3 and G). There are eight control point characterizations, one for each of four possible symmetrizations of the configuration and one for each of two possible boundary conditions. If all four symmetrizations are not defined (i.e., if there is only one or no planes of symmetry in the problem or if flow symmetry exists, then those characterizations of the control point which are not required are given as "NULL", which means that no row of the AIC matrix will be created for this boundary condition and symmetrization. Table 8.3 lists the abbreviations of the possible characterization labels of the control point and explains what they mean.

Following all of the control point data the boundary condition data is printed. This information is provided in the same sequence as the control point information discussed above. The data printed includes the control point index, the fine grid lattice indices of the point and a summary of the values of the non-zero left hand side boundary condition coefficients for each of the boundary conditions at the point. Table 8.4 lists the abbreviations used in the output, the symbols used in the PAN AIR Theory Document to represent the coefficients in the general boundary condition equation and the description of the values of the coefficients. Note that if all possible coefficients are zero (e.g. a MATCH DBLT boundary condition), the characterization of the control point is printed. These are listed in table 8.3. Note also that the boundary condition data for fifteen control points is printed on each page of output. Thus large problems might generate many pages of output if this option is invoked.

The DQG output ends with the printing of the module name and version, the date and time of execution and the elapsed time (CP seconds) used by DQG.

### 8.1.4 MAG Output

A summary table is printed which gives the number of near, intermediate and far field PIC's, and the number of closure, general and matching boundary condition AIC's. In addition, CPU time is printed for each execution of a MAG overlay, as well as for total influence coefficient computation. During processing, if an error occurs, a diagnostic message is printed and the program is stopped. Such an error message (unless it indicates that a needed data base does not exist) will generally be of no meaning to the user, and signifies an error in the operation of the program rather than an error in the user inputs.

### 8.1.5 RMS Output

The printed output consists only of fatal error diagnostic messages (less than a page) pertaining to the singularity condition of the partition of the AIC matrices corresponding to the unknown lambda's during the solution process.

### 8.1.6 RHS Output

RHS output consists of a small number of warning messages and a number of fatal error messages which indicate a program error rather than a user error.

### 8.1.7 MDG Output

MDG printed output consists of a few lines indicating that a successful run has occured. If the run is not successful, a diagnostic program error message is given and execution stops.

### 8.1.8 PDP Output

The Point Data Processor produces two sections of output in the case of a normal run, one of these being optional.

In the first section, a report on estimated disk storage requirements is printed out for each case of user options. The user is urged to consult this report and to assign enough disk storage for subsequent PDP runs. This report is useful if the run aborts prematurely and no actual computer resource report is given.

The second section is optional and produced only if print selections are made for any of the flow quantities computed by PDP. The report starts with a printed page of the global data (which remain constant for a given PDP run) for the run. For each case of user options, the options selected are printed as the first page for the case. The rest of the report consists of the flow quantities selected for printing for each velocity computation, velocity correction and surface. The flow quantities associated with the network itself which do not vary from surface to surface are also printed, e.g., source and doublet strength, gradient of doublet strength, pressure coefficient in vacuum, etc., are independent of the surface. A 'REVERSE' option is available to the user, the effect of this being the reversal of the network surface, i.e., upper surface becomes the lower surface, etc. This is repeated for each image, network and solution selected. Each page of the report also contains the run and problem identifications, date of run, network, image and solution indices, the case number and all identifying labels as part of the report headers. The printed flow quantities consist of perturbation and total velocities, the perturbation, total and normal mass flux, gradient of doublet strength, vorticity angle for wake surfaces and pressures and local Mach numbers for isentropic, linear, second order, reduced second order and slender body approximations. Refer to section B.4 of this document for the definitions of these quantities.

Table 8.5 defines the headings in the second section in terms of the mathematical symbols used in this document and in the PAN AIR Theory Document (where applicable) and in terms of a short verbal description of the item.

Figure 8.7 illustrates a typical PDP output.

### 8.1.9 CDP Output

The Configuration Data Processor produces two sections of printed output. The first section lists problem specifications which includes global data (remains constant for a given CDP run), and case options data (varies over a given CDP run).

The second section lists forces and moments data which have been requested by the problem specifications. The data will follow the list of its corresponding set of case input parameters. The forces and moments printed are associated with the velocity correction, velocity computation method, pressure rule and axis system specified by the user. This is repeated for each image, network and solution selected. Selected forces and moments which are accumulated over selected sets of case input parameters may be printed.

Table 8.6 defines headings used in CDP output in terms of the typically used mathematical symbol and a short description. Figure 8.8 illustrates a typical CDP output.

### 8.1.10 PPP Output

The print-plot processor module obtains configuration geometry and control point data from DQG, pressure, velocity and related data from PDP and force and moment data from CDP. Depending upon the user selected options, the printed output ranges from a small number of lines to thousands of lines.

Table 8.7 defines the headings in the output of PPP in terms of the typically used mathematical symbol and in terms of a short description. In addition the index provided to DIP which selects this item is listed at the far right in the table. Figure 8.9 illustrates a typical PPP output. The PPP module also generates plot files of data from DQG, PDP and CDP data bases in a format suitable for processing by plot programs external to PAN AIR. A description of the plot file is given in section 8.3.

### 8.1.11 Warning and Error Messages

In addition to the standard output discussed above, warning and error messages may also be printed by programs in the PAN AIR system. This section discusses these in some detail.

Warning messages are primarily advisory in nature. They indicate that the module has encountered an unexpected or irregular condition that should not cause difficulties or errors but is sufficiently unusual that the user ought to verify that the situation is in fact what is desired. In some cases these cause the module to assume default values for some parameter. In these cases the module informs the user that the default has been assumed and where practical, also defines the default value.

Error messages are always fatal in the sense that only some portion of the module in which the error occurs will execute. Certain modules (DIP and DQG) allow a certain number of errors to accumulate before terminating execution. In others, execution terminates immediately.

There are three possible causes of PAN AIR-generated error messages. The first cause is a user error in the problem definition. These occur only in modules DIP and DQG and possibly (for one particular error only) in RMS. The second is an operating system error. The third possible cause is a program error, that is, a mistake in the code of one or more modules.

An error due to the first cause is fixed by finding the incorrect or faulty input data and by replacing it with the correct data. An error due to the second cause will usually disappear if the job is resubmitted. If it does not, the user must consult the representatives of the computer installation at which PAN AIR is being used. An error of the third cause usually requires modification of the software.

Sections 8.1.11.1 through 8.1.11.4 discuss errors which occur in each of the modules of PAN AIR. In addition to errors which occur within a module there are some errors which occur which are associated with the database management system, SDMS. These are labelled by the phrase "SDMS ERROR." Those SDMS errors which occur due to erroneous user input are discussed in section 8.1.11.5.

### 8.1.11.1 Errors in MEC

Error messages produced during execution of MEC occur as a consequence of errors in the MEC directives supplied by the user. The appropriate corrections should be obvious when the input data is examined. If they are not, then the user should study further section 6 of this manual, and should pay particular attention to the examples in section 6.3. The error messages in MEC should all be self-explanatory.

### 8.1.11.2 Errors in DIP

All error messages in module DIP occur as a consequence of some user error in the data provided to either DIP or MEC. The appropriate corrections are obvious when the individual input records are examined, especially if the appropriate part of section 7 of this document is consulted for comparison.

Warning messages produced by DIP usually advise the user that a particular default option has been selected. Usually this is of no consequence. Attention of the user is directed to it solely to assure that the resulting default is in accord with user expectations.

### 8.1.11.3 Error and Warning Messages in DQG

DQG produces error and warning messages as a result either of user errors or of program errors. The basic approach to processing errors in DQG is intended to provide information about what has happened, to describe where in the configuration the error has occurred and to allow the program to continue running sufficiently long so that if the indicated error occurs several places in the configuration, the user will be alerted to that fact.

This is all accomplished by printing a short description of the error that has occurred, followed by information regarding the location of the error in the configuration (e.g., network, identified by network index and panel, identified by column and row number, in which the error occurred). This is often followed by supplementary information which lists the erroneous or bad data. Within each major overlay of DQG up to ten errors can accumulate before all processing in the program stops. If ten or fewer errors occur, processing within that overlay will continue to completion but no subsequent overlay in DQG will be executed. In this manner several identical errors can be discovered with only one execution of the DQG module.

In order to make it easier to find a particular error message, the errors have been grouped by overlay. Recall that DQG prints a statement concerning elapsed CPU time at the end of each overlay. This statement labels the end of each overlay. Each of the following tables is labelled by a similar statement. The error messages in each table will occur after the printing of the statement which heads the table and before the printing of the next similar statement.

Only errors which might be due to user errors are listed in the tables. Two other types of errors might occur. PROGRAM ERRORS are lablled as such at the time the error message is printed. If one of these occurrs the user must consult with the maintenance staff of PAN AIR. The data accompanying these error messages is intended to be of use to the programmer and not to the user. For this reason no detailed discussion of these messages is provided. The second type of error which might occur is an SDMS error. These are discussed in section 8.1.11.5.

Tables 8.8 through 8.14 describe the possible errors for each overlay of the DQG module. The possible warning messages generated by DQG are described in tables 8.15 through 8.20.

### 8.1.11.4 Error Messages in MAG, RMS, RHS, MDG, PDP amd CDP

All error messages in these modules occur due to program errors (except for one error in RMS as mentioned below). Users should consult with those responsible for maintaining PAN AIR if any errors occur in these modules. The messages in these modules will not be explained further.

Certain warning messages are produced in RHS which involve the selection by RHS of a vanishing right hand side term for the indicated boundary condition. The user should assure that this is indeed the required boundary condition if such a message is encountered.

One user-caused error in RMS might occur. If the user defines an ill-posed boundary value problem, RMS may discover a singular matrix. In this case the error message "SINGULAR MATRIX....." will be printed by RMS. The appropriate action is to redefine the problem so that it is no longer an ill-posed problem. A discussion of well-posed boundary value problems may be found in section A.3 of this document.

### 8.1.11.5 SDMS Error Messages

Errors diagnosed by the database manager system SDMS are not as self explanatory as other error diagnostics in PAN AIR. A message to the effect that an SDMS error has occurred is printed along with one or two error codes. These error codes correspond to entries in a table in section 13 of the PAN AIR Maintenance Document. The errors are explained in the table.

SDMS errors can occur because of user errors, operating system errors and/or program errors. The table mentioned above is often not easy to interpret. For this reason, we list in tables 8.21 through 8.23 those SDMS

errors which might be due to either user or operating system errors and indicate the user action which will probably correct the difficulty. If an SOMS error is encountered which is not listed in the following tables or if the recommeded modification does not correct the problem, the user is advised to consult with those responsible for the maintenance of PAN AIR.

## 9.2 Permanent Data Base

All PAN AIR modules create a permanent data base except for MEC and PPP. The MEC module creates a temporary data base which is used by all other modules. Tables 9.24 through 9.31 give the dataset names of the permanent data bases and a short definition of what each data set contains.

The complete master definition of each database created by each module in the PAN AIR system is given at the end of each appropriate section of the PAN AIR Maintenance Document.

If database files are saved at the end of execution of a job through the use of the KEEP directive to MEC (see section 6), the user may access the database files to obtain additional information which resides there. Section 1 of the PAN AIR Maintenance Document provides some guidance concerning how the user may write a FORTRAN program to accomplish this database access.

## 9.3 Plot Data File

The PPP module prepares plot files of data from DQG, PDP and CDP in a format suitable for processing by plot programs external to PAN AIR.

### 9.3.1 DQG Plot File

The preparation of network geometry for three-dimensional plots from the DQG data base consists of the following:

(1.) Run identification (40 characters)

(2.) DQG global data

(3.) Geometry corner point data at selected networks consisting of row number, column number, number of points, and X, Y, Z coordinates.

Tables 9.32, 9.33 and 9.34 describe the format of the geometry plot file.

### 9.3.2 PDP Plot File

The PPP module prepares data for plotting at control points along columns or rows of panels, including any control points on network edges.

Preparation of the point data for two-dimensional plots from the PDP data base consists of the following:

(1) Run identification (40 characters) that consists of information concerning case, solution, and network numbers, point location type, selected row/column location, and selected option types

(2) Parameter name list of the selected options

(3) PDP global data

(4) Plot titles

(5) Titles associated with the parameters in file

(6) Data format (if used)

(7) Plot data (formatted or free field).

Tables 8.35, 8.36 and 8.37 describe the format of the plot file.

### 8.3.3 CDP Plot File

The PPP module prepares data for plotting CDP data by case, solution, and networks.

The preparation of the configuration data file for two-dimensional plots from CDP data base is similiar to the PDP plot data file formatting.

Tables 8.38, 8.39 and 8.40 describe the format of the plot file.

## 8.4 Analyzing the CHECK DATA Run

To aid the user in correctly defining the complex geometry required to solve realistic flow problems PAN AIR offers a CHECK DATA mode of operation in which only the DIP or the DIP and DQG modules are executed. These provide the user with many diagnostic aids and information which he can use to assure that the problem he wishes to solve has been correctly described and interpreted by the PAN AIR system.

This section is a guide for the first-time user of PAN AIR to point out what items in the DIP and DQG output should be examined to assure that the problem is correctly defined. An absence of error messages in the CHECK DATA will assure that the problem can be solved by the PAN AIR system, but it does not mean that the problem is what the user thinks he has defined. To assure that the user's concept of the problem is in accord with PAN AIR's interpretation of the problem, the user must study certain items of the output with care.

The only sensible way to perform a CHECK DATA run is with all print options turned on for both the DIP and DQG modules. Note that this can lead

to a large volume of output (see sections 8.1.2 and 8.1.3). Thus record G17 with option ALL (see section 7.3) ought to be included in the input deck for a CHECK DATA run.

The first items to look for are errors which might have occured during execution. Only if no errors are found can the printed output be examined with confidence.

Once all errors are eliminated the user should examine all warning messages, consulting section 8.1.11.3 if necessary and should determine whether the input should be revised to eliminate questionable aspects of the problem. After all errors are eliminated and the warning messages are understood, the true analysis of the run begins.

First the MEC output should be checked to assure that the database files have been properly defined (that is, that the file names and identifiers are what the user expects). Following this the user should examine the Global Data Summary provided by DIP. Check that the Mach number and the compressibility direction are correct, that the symmetry properties of the problem are as expected and that the list of solutions includes all those of interest. Then examine the Network Data and assure that the singularity types and boundary conditions are in agreement with expectations.

If all these items agree with user expectations, the DQG output should then be examined. In the printed list of panel corner point coordinates, check that any network edge which has collapsed (labelled by CHANGED) should in fact be collapsed, and assure that supposedly collapsed edges are if fact collapsed (labelled by CHANGED).

Then the empty space abutment descriptions should be examined in order to be sure that no abutments have been missed. Check that each edge segment in the empty space abutment list is not supposed to meet any other network edges. When the empty space abutment list has been verified, examine the abutment list to be sure that the correct sets of network edges meet together. If any network edges were labelled as NO DOUBLET EDGE MATCHING edges (record N13 of section 7.4), then the user should check that the start, edge and end points of that network edge are labelled by NM in the abutment description.

Next the DQG Global Data Summary should be examined. Again verify the Mach number and compressibility direction. Check the size of the AIC matrix to assure that sufficient resources have been allocated to allow MAG to run to completion. Examine the network list and verify especially that the source and doublet edge types are correct.

Following the examination of the global data, the control point data output ought to be checked. Here the user should look closely at the normal vector at each control point to determine the outward surface of the network. Then the user should make sure that he has chosen the correct upper or lower surface boundary conditions to correspond with the network orientation.

Those users who have selected class 3, 4 or 5 boundary conditions are advised to examine the boundary condition data closely. In this output the values of the non-vanishing coefficients in the general boundary condition equation are listed. (See PAN AIR Theory Document, sections 5 and H).

If all of the above items are in agreement with the user's expectations, then PAN AIR's understanding of the problem is in accordance with the user's concept of the problem.

## 8.5 Control Card Procedure File

To free the user from the necessity of preparing large control card decks to run PAN AIR, the MEC module creates a file of control cards which is sufficient to execute most PAN AIR problems.

### 8.5.1 General Structure of File

The MEC control card file is called MECCC. The basic operations which the control card file performs are:

1) obtains a copy of a file which contains the next module which is to be executed;

2) executes a module of PAN AIR;

3) purges a set of database files.

The exact nature of the cards which perform these operations depends on the installation's operating system. Figures 8.10 to 8.13 illustrate the contents of a typical MECCC file for the four standard operating systems under which PAN AIR was initially installed.

### 8.5.2 Modification of Control Card Files

Under some circumstances (notably for solving large problems with PAN AIR) the control card file generated by MEC is not adequate. In this case one or several control cards must be modified. A discussion of the exact modifications required in various circumstances is contained in Appendix C. The most effective method to modify the control card file is to execute MEC, create the MECCC control card file and copy the file to the local operating system card punch file. This will create a deck of cards which can easily be modified and resubmitted to complete the execution of the full PAN AIR system. Note that the card deck must be appended to the original card deck that caused MEC to execute.

| | |
|---|---|
| NOS | No source |
| SA | Source analysis |
| SD1 | Source design |
| NOD | No doublet |
| DA | Doublet analysis |
| DD1 | Doublet design |
| DW1 | Doublet wake, type 1 |
| DW2 | Doublet wake, type 2 |

Table 8.1 - Abbreviations for source and doublet types

| | |
|---|---|
| MATC | Matching edge |
| NON | Non-matching edge |
| NO | No doublet matching edge |
| CLOS | Closure edge |

Table 8.2 - Abbreviations used for source/doublet edge types

| | |
|---|---|
| NULL | No boundary condition is imposed and no AIC row is created for this type of characterization. |
| AERODYNAM | A linear combination of one or more of the following quantities defines the boundary condition imposed:<br>Potential<br>Normal Mass Flux<br>Velocity<br>All are average quantities. |
| SING SPEC | A boundary condition which specifies either source strength, doublet strength or gradient of doublet strength is imposed at the point. This boundary condition is imposed only when the singularity specification which is imposed does not create a known singularity parameter. |
| KNOWN DBLT | The boundary condition imposed defines a known doublet singularity parameter. |
| KNOWN SRC | The boundary condition imposed defines a known source singularity parameter. |
| CLOSURE | A closure boundary condition is imposed over the rows or columns of the network. |
| MATCH DBLT | A doublet matching boundary condition is imposed at the control point. |
| MATCH SRC | A source matching boundary condition is imposed at the control point. |

Table 8.3 - Control point characterizations

| ABBREVIATION | SYMBOL | DESCRIPTION |
|---|---|---|
| MFLUX | $A_A$ | Coefficient of mass flux |
| SRC | $A_D$ | Coefficient of source strength |
| POT | $C_A$ | Coefficient of potential |
| DBLT | $C_D$ | Coefficient of doublet strength |
| VTANX | $V_x$ | Coefficient of tangent vector for tangent to average surface |
| VTANY | $V_y$ | See VTANX |
| VTANZ | $V_z$ | See VTANX |
| DTANX<br>DTANY | | Tangent vector for evaluation of gradient of doublet strength. |
| MATCH SRC | | Indicates that a source matching boudary condition will be imposed at the point. |
| MATCH DBL | | Indicates that a doublet matching boundary condition will be imposed at the point. |
| KNOWN SRC<br>KNOWN DBLT | | Indicates that the boundary condition results in known singularity parameters. |
| CLOSURE | | Indicates that closure boundary conditions will be imposed at the point. |
| NULL | | Indicates that no boundary conditions are defined for this control point and boundary condition. |

Table 8.4 - Boundary condition coefficient abbreviations

| PDP Headings | Math. Symbol | Quantity | PDP Keyword | DIP Index |
|---|---|---|---|---|
| ROW | | Point, row index | POINT | 1 |
| COL | | Point, column index | | 1 |
| X-CORD | $x_o$ | Point, x-coordinate, RCS | XYZ | 2 |
| Y-CORD | $y_o$ | Point, y-coordinate, RCS | | 2 |
| Z-CORD | $z_o$ | Point, z-coordinate, RCS | | 2 |
| PWX | $w_x$ | x-component, Perturbation mass flux | PWXYZ | 3 |
| PWY | $w_y$ | y-component, Perturbation mass flux | | 3 |
| PWZ | $w_z$ | z-component, Perturbation mass flux | | 3 |
| WX | $W_x$ | x-component, Total mass flux | WXYZ | 4 |
| WY | $W_y$ | y-component, Total mass flux | | 4 |
| WZ | $W_z$ | z-component, Total mass flux | | 4 |
| WMAG | W | magnitude, Total mass flux | WMAG | 5 |
| WN | $W_n$ | normal component, Total mass flux | WN | 6 |
| PVX | $v_x$ | x-component in RCS Perturbation velocity | PVXYZ | 7 |
| PVY | $v_y$ | y-component in RCS, Perturbation velocity | | 7 |
| PVZ | $v_z$ | z-component in RCS, Perturbation velocity | | 7 |
| VX | $V_x$ | x-component in RCS, Total velocity | VXYZ | 8 |
| VY | $V_y$ | y-component in RCS, Total velocity | | 8 |
| VZ | $V_z$ | z-component, Total velocity | | 8 |

Table 8.5 - PDP headings

| PDP Headings | Math. Symbol | Quantity | PDP Keyword | DIP Index |
|---|---|---|---|---|
| VMAG | V | Magnitude, Total velocity | VMAG | 9 |
| PHI | $\phi$ | Perturbation potential | PHI | 10 |
| PHIT | $\bar{\phi}$ | Total potential | PHIT | 11 |
| MLISEN | M | Local Mach number, isentropic | ML | 12 |
| MLLINE | M | Local Mach number, linear | | 12 |
| MLSECO | M | Local Mach number, second-order | | 12 |
| MLREDU | M | Local Mach number, reduced second-order | | 12 |
| MLSLEN | M | Local Mach number, slender body | | 12 |
| CPISEN | $C_p$ | Pressure coefficient, isentropic | CP | 13 |
| CPLINE | $C_p$ | Pressure coefficient, linear | | 13 |
| CPSECO | $C_p$ | Pressure coefficient, second-order | | 13 |
| CPREDU | $C_p$ | Pressure coefficient, reduced second-order | | 13 |
| CPSLEN | $C_p$ | Pressure coefficient, slender body | | 13 |
| GMUX | $\partial\mu/\partial x$ | Doublet strength gradient, x-component | GMUXYZ | 14 |
| GMUY | $\partial\mu/\partial y$ | Doublet strength gradient, y-component | | 14 |
| GMUZ | $\partial\mu/\partial z$ | Doublet strength gradient, z-component | | 14 |
| PSI | $\psi$ | Angle between average total velocity and surface vorticity (degrees) | PSI | 15 |
| SINGS | $\sigma$ | Singularity strength, source | SING | 16 |
| SINGD | $\mu$ | Singularity strength, doublet | | 16 |
| SPDMAX | $V_m$ | Maximum total speed | SPDMAX | 17 |
| SPDCRT | $V_{cr}$ | Critical speed | SPDCRT | 18 |
| CPVAC | $C_{pv}$ | Pressure coefficient, vacuum | CPVAC | 19 |

Table 8.5 - Continued

| PDP Headings | Math. Symbol | Quantity |
|---|---|---|
| CPCISN | $C_{pc}$ | Critical pressure coefficient-isentropic |
| CPCLIN | $C_{pc}$ | Critical pressure coefficient-linear |
| CPCSO | $C_{pc}$ | Critical pressure coefficient-second order |
| CPCRSO | $C_{pc}$ | Critical pressure coefficient-reduced second order |
| CPCSB | $C_{pc}$ | Critical pressure coefficient-slender body |
| B.C. | | Boundary Conditions |
| VIC | | Velocity Influence Coefficient |
| SA1 | | Stagnation to ambient (Correction 1) |
| SA2 | | Stagnation to ambient (Correction 2) |
| UNIFVL | $U_\infty$ | Uniform onset flow velocity |
| ALPHA | $\alpha$ | Angle of attack (degrees) |
| BETA | $\beta$ | Angle of sideslip (degrees) |
| CALPHA | $\alpha_C$ | Angle of attack defining compressibility direction (degrees) |
| CBETA | $\beta_C$ | Angle of sideslip defining compressibility direction (degrees) |

Table 8.5 - Concluded

| CDP Headings | Math. Symbol | Quantity | |
|---|---|---|---|
| FX | $C_{Fx}$ | Force, x-coordinate | Various Axis Systems |
| FY | $C_{Fy}$ | Force, y-coordinate | |
| FZ | $C_{Fz}$ | Force, z-coordinate | |
| MX | $C_{Mx}$ | Moment, x-coordinate | |
| MY | $C_{My}$ | Moment, y-coordinate | |
| MZ | $C_{Mz}$ | Moment, z-coordinate | |
| ISEN | | Isentropic | |
| LINE | | Linear | |
| SECO | | Second-order | |
| REDU | | Reduced second-order | |
| SLEN | | Slender body | |
| RCS | $x_o\ y_o\ z_o$ | Reference coordinate system | |
| WAS | | Wind axis system | |
| BAS | | Body axis system | |
| SAS | | Stability axis system | |
| HAS | | Hinge moment axis | |
| ALPHA | $\alpha$ | Angle of attack (degrees) | |
| BETA | $\beta$ | Angle of sideslip (degrees) | |
| UNIF | $U_\infty$ | Uniform onset flow velocity | |
| B.C. | | Boundary condition | |
| CALPHA | $\alpha_c$ | Compressibility angle of attack (degrees) | |
| CBETA | $\beta_c$ | Compressibility angle of sideslip (degrees) | |
| V.I.C. | | Velocity influence coefficient | |
| MACH | $M_\infty$ | Free stream mach number | |

Table 8.6 - CDP headings

PPP Headings for PDP

| PPP Headings | Math. Symbol | Quantity | DIP Index |
|---|---|---|---|
| X | $x_o$ | Point, x-coordinate | 2 |
| Y | $y_o$ | Point, y-coordinate | 2 |
| Z | $z_o$ | Point, z-coordinate | 2 |
| PWX | $w_x$ | Perturbation mass flux, x-component | 3 |
| PWY | $w_y$ | Perturbation mass flux, y-component | 3 |
| PWZ | $w_z$ | Perturbation mass flux, z-component | 3 |
| WX | $W_x$ | Total mass flux, x-component | 4 |
| WY | $W_y$ | Total mass flux, y-component | 4 |
| WZ | $W_z$ | Total mass flux, z-component | 4 |
| WMAG | W | Total mass flux, magnitude | 5 |
| WN | $W_n$ | Total mass flux, normal component | 6 |
| PVX | $v_x$ | Perturbation velocity, x-component | 7 |
| PVY | $v_y$ | Perturbation velocity, y-component | 7 |
| PVZ | $v_z$ | Perturbation velocity, z-component | 7 |
| VX | $V_x$ | Total velocity, x-component | 8 |
| VY | $V_y$ | Total velocity, y-component | 8 |
| VZ | $V_z$ | Total velocity, z-component | 8 |
| VMAG | V | Total velocity, magnitude | 9 |

Table 8.7 - PPP headings

| PPP Headings | Math. Symbol | Quantity | DIP Index |
|---|---|---|---|
| PHI | $\phi$ | Perturbation potential | 10 |
| PHIT | $\bar{\phi}$ | Total potential | 11 |
| MLISEN | M | Local Mach number, isentropic | 12 |
| MLLINE | M | Local Mach number, linear | 12 |
| MLSECO | M | Local Mach number, second-order | 12 |
| MLREDU | M | Local Mach number, reduced second-order | 12 |
| MLSLEN | M | Local Mach number, slender body | 12 |
| CPISEN | $C_p$ | Pressure coefficient, isentropic | 13 |
| CPLINE | $C_p$ | Pressure coefficient, linear | 13 |
| CPSECO | $C_p$ | Pressure coefficient, second-order | 13 |
| CPREDU | $C_p$ | Pressure coefficient, reduced second-order | 13 |
| CPSLEN | $C_p$ | Pressure coefficient, slender body | 13 |
| GMUX | $\partial\mu/\partial x$ | Doublet strength gradient, x-component | 14 |
| GMUY | $\partial\mu/\partial y$ | Doublet strength gradient, y-component | 14 |
| GMUZ | $\partial\mu/\partial z$ | Doublet strength gradient, z-component | 14 |
| PSI | $\psi$ | Angle between average total velocity and surface voticity (degrees) | 15 |
| SINGS | $\sigma$ | Singuarity strength, source | 16 |
| SINGD | $\mu$ | Singularity strength, doublet | 16 |
| SPDMAX | $V_m$ | Maximum total speed | 17 |
| SPDCRT | $V_{cr}$ | Critical speed | 18 |
| CPVAC | $C_{pv}$ | Pressure coefficient, vacuum | 19 |

*Table 8.7 - Continued*

| PPP Headings | Math. Symbol | Quantity |
|---|---|---|
| BOUN | | Boundary conditions |
| SA1 | | Stagnation to ambient (Correction 1) |
| SA2 | | Stagnation to ambient (Correction 2) |
| UNIF | $U_\infty$ | Uniform onset flow velocity |
| ALPHA | $\alpha$ | Angle of attack (Degrees) |
| BETA | $\beta$ | Angle of sideslip (Degrees) |
| FX | $C_{Fx}$ | Force, x-coordinate |
| FY | $C_{Fy}$ | Force, y-coordinate |
| FZ | $C_{Fz}$ | Force, z-coordinate |
| MX | $C_{Mx}$ | Moment, x-coordinate |
| MY | $C_{My}$ | Moment, y-coordinate |
| MZ | $C_{Mz}$ | Moment, z-coordinate |
| ISE | | Isentropic |
| LIN | | Linear |
| SEC | | Second-order |
| RED | | Reduced second-order |
| SLE | | Slender body |
| RC | | Reference coordinate system |
| WA | | Wind axis system |
| BA | | Body axis system |
| SA | | Stability axis system |

Note: Combinations of (FX, FY, FZ, MX, MY, MZ) with (ISE, LIN, SEC, RED, SLE) with (RC, WA, BA, SA) are used. Example: FYLINWA means y component of force with linear pressure rule in the wind axis system.

Table 8.7 - Concluded

"0,0 OVERLY ELAPSED CPU TIME...."

RUN, PROBLEM AND USER ID'S NOT FOUND
ON THE MEC DATABASE

This indicates MEC did not correctly create a MEC database. Check the MEC input data to assure that no errors have been made. If no errors are found this might be a program error in MEC. Consult those responsible for the maintenance of PAN AIR.

NO NETWORKS DEFINED

The user has failed to define networks in the input to DIP. Define the networks for the configuration and rerun DIP (see section 7.4 of this manual).

ZERO LENGTH ABUTMENT

| USER ABUTMENT INDEX | | 3 | |
|---|---|---|---|
| NETWORK | EDGE | START PT | END PT |
| 1 | 2 | 3 | 3 |

The user has defined an abutment with identical start and end points. In the example above the third abutment in the BEGIN GEOMETRIC EDGE MATCHING portion of DIP input was erroneously defined to extend from point 3 on edge 2 to point 3 on edge 2. Correct the abutment description and rerun DIP.

Table 8.8 - Error messages in DQG overlay (1,0)

"1,0 OVERLY ELAPSED CPU TIME ...."

NETWORK (UPPER-WING ) EDGE 3
SOURCE DESIGN 1 NETWORK WITH NON-MATCHING
EDGE CANNOT BE COLLAPSED

DQG has attempted to collapse a non-matching edge of a source design network. If this edge is required to be collapsed, the source type of the network has to be redefined and DIP must be rerun. If the edge should not be collapsed then either the network geometry must be redefined or a larger value must be chosen for the TRIANGULAR PANEL TOLERANCE, (see record N7 of section 7.4).

NETWORK (FOREBODY ) EDGE 2
AVERAGE PANEL LENGTH EXCEEDS TOLERANCE
BUT THE MINUMUM DOES NOT. THE EDGE
CANNOT BE COLLAPSED.

There is at least one panel edge on the indicated network edge which is short compared to the TRIANGLE PANEL TOLERANCE but most of the edges are longer. If the edge is supposed to be collapsed, the TRIANGLE PANEL TOLERANCE must be increased and DIP needs to be rerun. If the edge is not supposed to be collapsed, the TRIANGLE PANEL TOLERANCE should be reduced. It is possible that the coordinates of one or more points on the indicated edge are in error. Check the coordinates of the network for errors.

TWO ADJACENT EDGES HAVE ZERO LENGTH
NETWORK UPPER-WING EDGES 1 2

An attempt was made to collapse two adjacent network edges. Either the network coordinates are in error or the value of the TRIANGLE PANEL TOLERANCE needs to be decreased. (See record N7 of section 7.4).

INTERIOR PANEL IS TRIANGULAR
NETWORK UPPER-WING PANEL COLUMN 5 AND ROW 2

Either there is an error in the coordinates of the corner points of that panel (and possibly some others adjoining it), or the TRIANGLE PANEL TOLERANCE is too large. Check the geometry, redefine it if necessary or change the tolerance distance and rerun DIP.

ASPECT RATIO = 0.6934E+06
NETWORK UPPER-TAIL PANEL COLUMN 3 AND ROW 8

The aspect ratio for the indicated panel exceeds the limits of 10,000. Redefine the geometry and rerun DIP.

Table 8.9 - Error messages in DQG overlay (2,0)

"2,0 OVERLY ELAPSED CPU TIME ...."

```
ERRONEOUS USER ABUTMENT DATA
OVERLAPPING ABUTMENTS
  NETWORK   LOWER-WING          EDGE 3
  OVERLAP FROM COLUMN       3  ROW      5
  TO COLUMN                 7  ROW      5
```

The user has defined two abutments which refer to the same part of one network edge. Redefine abutment data so that the two abutments do not overlap or allow the automatic abutment search procedure to find the abutments.

```
ERRONEOUS USER ABUTMENT DATA
  USER ABUTMENT NUMBER            3
  NETWORK     EDGE       START-X    START-Y    END-X    END-Y
        2        5             1          1        7        1
        2        3             7          1        7        7
```

Some data items in the abutment description are in error. (In the example above, networks cannot contain a fifth edge.) Find the error in the data, correct it and rerun DIP.

Note that the data provided is an abutment description (see section 8.1.3). START-X and START-Y are the column and row indices of the starting point of the abutment and END-X and END-Y are the column and rows of the end points of the abutment.

```
NETWORK EDGES TOO FAR APART FOR ABUTMENT
     USER ABUTMENT NUMBER     3
    NETWORK     EDGE       START-X     START-Y     END-X       END-Y
          1        1             1           1         6           6
          5        1             6           1         3           1
         2TH NETWORK EDGE IN LIST GT  1.357E+15
         FROM FIRST NETWORK EDGE IN LIST
```

An abutment was defined for two network edges that are too far apart. If abutment is correct and geometry cannot be modified, then this error can be avoided if a full description of the abutment is provided as input to DIP. (See section 7.5, record GE2). That is the network, edge and point pairs must be given for all networks in the indicated abutment.

Table 8.10 - Error messages in DQG overlay (3,1)

"3,1 OVERLY  ELAPSED CPU TIME ..."

```
TOO MANY NETWORK EDGES IN ABUTMENT
THIS MAY ARISE EITHER FROM HAVING TOO
MANY NETWORK EDGES COMING TOGETHER IN
A SINGLE ABUTMENT OR FROM THE SAME
NETWORK EDGES TAKING PART IN TOO MANY
ABUTMENTS
   NETWORK        EDGES
         1            1
         2            1
         3            2
         4            1
         5            3
         6            4
         7            2
         8            4
         9            1
        10            3
        11            3
```

Check geometry of listed networks. If geometry is correct and networks should not be in an abutment together, reduce the TOLERANCE FOR GEOMETRIC NETWORK EDGE MATCHING, record G7 of section 7.3, or turn off automatic abutment search and define abutments as in section 7.5.

```
UPDATABLE NETWORK EDGE ABUTTING
A NON-UPDATABLE NETWORK EDGE
  ABUTMENT INDEX          3
    NETWORK      EDGE     START-X    START-Y     END-X       END-Y
          1         1           1          1         5           1
          2         3           3          3         1           3
   UPDATABLE FLAG       1          0
```

This is a warning unless the current run is an update run. The update run cannot be made. The edge of the non-updatable network must be relabelled as being updatable. In the example above, network 2 edge 3 is non-updatable. The original run must be repeated completely and then the update run may be attempted.

Table 8.11 - Error messages in DQG overlay (3,2)

MORE THAN ONE MATCHING EDGE IN ABUTMENT

ABUTMENT INDEX 9

| NETWORK | EDGE | START-X | START-Y | END-X | END-Y |
|---|---|---|---|---|---|
| 5 | 1 | 1 | 1 | 7 | 1 |
| 6 | 1 | 1 | 1 | 3 | 1 |

Only one "matching edge" may occur in an abutment. Either the edge types or network types must be redefined or the configuration must be changed and DIP must be rerun. (See record N12 or section 7.4).

NETWORK ENCOUNTERED WHICH PARTIALLY LIES ON A PLANE OF SYMMETRY

NETWORK PLANAR-BODY PLANE OR SYMMETRY 1

NUMBER OF POINTS OFF P-O-S 20

NUMBER OF POINTS ON P-O-S 10

If network should lie on plane of symmetry it need not do so exactly if the SYMMETRY PLANE NETWORK option is selected (see record N5 of section 7.4). Thus by turning on this option the error will be eliminated. If network should not lie in plane of symmetry, either change geometry of network or reduce the TOLERANCE FOR GEOMETRIC NETWORK EDGE MATCHING (Record G7 of section 7.3).

AUTOMATIC ABUTMENT SEARCH FAILURE MAY CAUSE PROBLEMS LATER

| NETWORK | EDGE | START-X | START-Y | END-X | END-Y |
|---|---|---|---|---|---|
| 1 | 1 | 1 | 1 | 5 | 1 |

Abutments involving indicated network edge not found in automatic abutment search. Change TOLERANCE FOR GEOMETRIC NETWORK EDGE MATCHING (increase if network edge should be in abutment, decrease if network should not be in abutment), change geometry of configuration or turn off automatic abutment search by defining abutments as in record GE2 of section 7.5.

TOO MANY NETWORKS IN ABUTMENT

| NETWORK | EDGE | START-X | START-Y | END-X | END-Y |
|---|---|---|---|---|---|
| 1 | 1 | 1 | 1 | 3 | 1 |
| 2 | 1 | 6 | 1 | 1 | 1 |
| 3 | 1 | 4 | 1 | 1 | 1 |
| 4 | 1 | 1 | 1 | 5 | 1 |
| 5 | 1 | 7 | 1 | 1 | 1 |
| 6 | 1 | 8 | 1 | 1 | 1 |

Only five or fewer network edges can form an abutment. If more than five networks truly form the abutment, then redefine the problem and rerun the programs. If not, then either decrease the TOLERANCE FOR GEOMETRIC NETWORK EDGE MATCHING (record G7 of section 7.3) or define abutments as in record GE2 of section 7.5.

Table 8.11 - Concluded

"3,0 OVERLY  ELAPSED CPU TIME ..."

```
MACH INCLINED PANEL AND/OR SUBPANEL
  NETWORK FIN
  PANEL COLUMN      2
  PANEL ROW       6
  NORMAL-CONORMAL INNER PRODUCT  1.378E-13
```

Change Mach number or modify geometry of indicated panel so that $\hat{n}\cdot\tilde{n} \neq 0$, and rerun DIP.

```
VANISHINGLY SMALL INNER AND OUTER SUBPANELS
  NETWORK WING
  EDGE  2
  CORNER PT COLUMN      8
  CORNER PT ROW         1
  SUBPANEL NUMBER       2
  PT   1.000E-11    2.000E-11    2.000E-11    1.000E-11  ....
       0.000E 00    0.000E 00    1.000E-11    1.000E-11  ....
       0.000E 00    0.000E 00    0.000E 00    0.000E 00  ....
```

Panel is too small. Redefine geometry so smallest panel has edge length greater than 1.000E-10.

```
NON-CONVEX PANEL WITH CORNER POINT
CLOSE TO PANEL CENTER POINT
  NETWORK  WING
  EDGE          3
  CORNER PT COLUMN            5
  CORNER PT ROW               3
  SUBPANEL NUMBER             3
```

Non-convex panels are permitted but the center point cannot be too close to one of the corner points (see section B.1.3). Redefine network geometry by moving offending corner point by some small distance (say, one-tenth of the length of one panel edge), and rerun DIP.

```
TANGENT VECTOR PROJECTION TO PANEL
IS LESS THAN HALF OF TANGENT VECTOR MAGNITUDE
  NETWORK  WING
  PANEL COLUMN     3
  PANEL ROW        2
  USER CLASS
  TANGENT VECTOR  XXXXXXXXXX
```

Where XXXXXXXXXX may be one of UPPER, LOWER, AVERAGE, DIFFERENCE or RHS, referring to the tangent vectors for the upper, lower, average and difference surfaces and the right hand sides. The tangent as defined is not sufficiently parallel to the panel in question. Redefine the tangent vector and rerun DIP (see record N16 of section 7.4).

Table 8.12 - Error messages in DQG overlay (4,0)

```
TANGENT VECTOR MAGNITUDE TOO SMALL
  NETWORK WING
  PANEL COLUMN            4
  PANEL ROW               1
  USER CLASS
  TANGENT VECTOR  XXXXXXXXXX
```

See above for explanation of XXXXXXXXXX. Tangent vector as defined is not a normalizable vector. Redefine tangent vector and rerun DIP. See record N16 or section 7.4.

```
NO USER SPECIFIED BOUNDARY CONDITION
  NETWORK HOR-STABIL
    FINE GRID COLUMN INDEX        2
    FINE GRID ROW INDEX           2
```

No boundary conditions were provided for network. Add desired choices from records N14, N15 and N16 of section 7.4 and rerun DIP.

Table 8.12 - Concluded

"4,0 OVERLY ELAPSED CPU TIME ...."

INCORRECT SELECTION OF XI-ETA VECTORS

| XI | ETA | ZETA | POINT | PO | VECTOR |
|---|---|---|---|---|---|
| ..... | | | | | |
| ..... | | | | | |
| ..... | | | | | |

This might be either an error in the corner point coordinates of the network or it might be a program error. Check the coordinates of the network to assure that two adjacent network corner points do not have the same coordinate. Look in the vicinity of the coordinates in the column labelled POINT. If no such error is encountered, consult with those responsible for the maintenance of PAN AIR.

SINGULAR LEAST SQUARES FIT
NETWORK INDEX 7
LATTICE INDEX-X 9
LATTICE INDEX-Y 6
DEVIATION FROM UNITY 1.377E 00

A singular outer spline was discovered. This may be due to poor paneling or it might be a program error. If an exotic paneling technique has been employed, try a more conventional one. If the paneling is not unusual, consult with those responsible for the maintenance of PAN AIR.

In version 1.0, a triangular design network (which is not permissible) may cause this message.

Table 8.13 - Error messages in DQG overlay (5,0)

"5,0 OVERLY ELAPSED CPU TIME ...."

```
SINGULAR INVERSE FOR SUBPANEL
TRANSFORMATION MATRIX
DUE TO INVALID MACH NUMBER
ONE MINUS MACH NUMBER SQUARED = 3.791E-16
```

Mach number is too close to unity. Change Mach number and rerun DIP.

```
MACH INCLINED PANEL DISCOVERED
    NETWORK UPPER-PLATE
    PANEL COLUMN     3
    PANEL ROW        5
```

Change Mach number or modify geometry and rerun DIP (see table 8.12).

```
LEAST SQUARES ERROR IN PANEL SUBSPLINE
     NETWORK BELLY
     PANEL COLUMN     9
     PANEL ROW        6
```

Poor panelling has resulted in a singular least squares fit for the panel spline. Modify geometry and rerun DIP.

```
MACH INCLINED SUBPANEL DISCOVERED
    NETWORK  TAIL
    PANEL COLUMN     9
    PANEL ROW        3
    SUBPANEL INDEX   7
```

Change Mach number or modify geometry and rerun DIP (see table 8.12).

Table 8.14 - Error messages in DQG overlay (6,0)

"1,0 OVERLY  ELAPSED CPU TIME ...."

ASPECT RATIO = 0.6394E+04
NETWORK UPPER-WING  PANEL COLUMN  3  AND ROW  9

The panel has an aspect ratio which exceeds 1000 but is less than 10,000. As a consequence the subpanel splines may be inaccurate over the surface of the panel. Check the coordinates of the corner points of this panel to assure that they are correct and recall when interpreting the output from PDP that the answers on this panel may be less accurate than the answers over other parts of the configuration.

Table 8.15 - Warning messages in DQG overlay (2,0)

---

"2,0 OVERLY  ELAPSED CPU TIME ..."

TOO MANY NEARBY NETWORK EDGES
SOME ABUTMENTS MAY BE MISSED
NETWORK FIN  EDGE  1

This message indicates that there are too many (more than twenty) network edges which lie close enough to the indicated network edge for the automatic abutment search procedure to work correctly. This may result in some fatal errors at a later time within this overlay. The recommeded correction to the user is to explicitly define the abutments for the indicated network edge (see record GE2 of section 7.5) and rerun the problem. It should not be necessary to define all of the abutments in the configuration. The automatic abutment search will find the remaining abutments.

It may also be that the TOLERANCE FOR GEOMETRIC NETWORK EDGE MATCHING value is much too large. Check this value before explicitly defining the abutments. If it is significantly larger that say a typical panel edge length, then try redefining it with a more sensible value.

Table 8.16 - Warning messages in DQG overlay (3,1)

"3,1 OVERLY  ELAPSED CPU TIME ..."

```
AUTOMATIC ABUTMENT SEARCH MAY HAVE
MISSED NETWORK ABUTMENT.  CHECK
ABUTMENT DESCRIPTION CAREFULLY
     NUMBER OF UNMATCHED EXPANDED ABUTMENTS       1
     NUMBER OF EXPANDED ABUTMENTS                 3
```

The automatic abutment procedure has found a network edge segment which lies near another network edge segment but the other network edge segment does not lie near enough to the first edge segment. Check the list of abutments carefully, especially the empty space abutments. If an abutment has been missed, the user can increase the TOLERANCE FOR GEOMETRIC NETWORK EDGE MATCHING (record G7 of section 7.3) or the user can define the troublesome abutment explicitly (record GE2 of section 7.5). If the abutments are correct, the message can be ignored. If the user wishes the message to disappear, it will probably be eliminated by reducing the TOLERANCE FOR GEOMETRIC NETWORK EDGE MATCHING, although there is a chance that some other abutment may be missed if the tolerance is reduced.

```
UPDATABLE NETWORK EDGE ABUTTING
A NON UPDATABLE EDGE
    ABUTMENT INDEX      3
  NETWORK    EDGE      START-X    START-Y     END-X      END-Y
       1       1           1          1          5          1
       2       3           3          3          1          3
        UPDATABLE EDGE          1              0
```

No IC update will be permitted for this case. If the user wishes to run an IC update for this problem he must define both indicated edges to be updatable. In the example above network 2, edge 3 must be labelled updatable (see record N8 of section 7.4).

```
MORE THAN TWO NETWORKS IN SMOOTH ABUTMENT
SMOOTH ABUTMENT TREATED AS NORMAL ABUTMENT
     ABUTMENT INDEX   4
   NETWORK    EDGE       START-X     START-Y      END-X       END-Y
        1       1           1           1           6           1
        3       2           4           1           4           3
        6       4           1           1           1           7
```

See explanation below.

Table 8.17 - Warning messages in DQG overlay (3,2)

```
SMOOTH ABUTMENT DEFINED WITH DESIGN NETWORK
SMOOTH ABUTMENT TREATED AS NORMAL ABUTMENT
     ABUTMENT INDEX 5
  NETWORK      EDGE        START-X      START-Y      END-X      END-Y
        4         1             1            1          3          1
        5         2             4            4          4          1
```

See explanation below.

```
NETWORK HAS TOO FEW PANELS FOR SMOOTH ABUTMENT
     ABUTMENT INDEX 6
  NETWORK      EDGE      START-X      START-Y      END-X      END-Y
        6         1           1            1          2          1
        5         3           6            7          1          7
  INDEX OF SMALL NETWORK      1
```

See explanation below.

```
VELOCITY OPTION NOT COMPATIBLE
     ABUTMENT INDEX  9
  NETWORK      EDGE      START-X    START-Y   END-X      END-Y
        1         3           4          5       1          5
        7         4           1          1       1          5
  VEL COMP METHODS       0        1
```

All of the above messages indicate the user has defined a smooth abutment which violates one or more of the rules for the application of smooth abutments. The abutments are redefined to be non-smooth. No user action is necessary unless the abutment must be smooth. To avoid the warning message, the smooth abutment choice should be eliminated from the input to DIP (see record GE4 of section 7.5).

```
MATCHING EDGE ABUTS A PLANE OF SYMMETRY.
RESULTS DEPEND ON THE CONFIGURATION.
THE AIC MATRIX MAY BE UNDERCONSTRAINED,
OVERCONSTRAINED, SINGULAR OR REASONABLY
CORRECT.  OTHER ERRORS MAY BE TRIGGERED
BUT PROCESSING WILL CONTINUE AND A
SOLUTION WILL BE ATTEMPTED.
      DOUBLET MATCHING IMPOSED AT ABUTMENT
```

The condition of a matching edge abutting a plane of symmetry can in certain circumstances lead to a variety of problems. It is recommended that (unless the offending edge is part of a wake network) the configuration be rearranged to avoid this situation. This may be accomplished by relabelling the edges of the network (see record N12 of section 7.4).

Table 8.17 - Continued

```
AUTOMATIC ABUTMENT SEARCH FAILURE
MAY CAUSE PROBLEMS LATER
  NETWORK      EDGE     START-X     START-Y    END-X     END-Y
        6         1           8           1        4         1
```

The automatic abutment search failed to find an abutment for the indicated network edge although one or more candidates were discovered. The user should check the empty space abutment list carefully. If an abutment has been missed, either the TOLERANCE FOR GEOMETRIC NETWORK EDGE MATCHING should be increased (record G7 of section 7.3) or the abutment should be defined explicitly by the user (record GE2 of section 7.5).

Table 8.17 - Concluded

"3,3 OVERLY ELAPSED CPU TIME...."

```
NO DOUBLET MATCHING AT NETWORK EDGE
    ABUTMENT INDEX    9
  NETWORK     EDGE     START-X    START-Y     END-X     END-Y
       10        2           4          1         4         3
       11        4           1          8         1         1
```

Boundary conditions which impose doublet matching will not be invoked at control points located at the edge midpoints along the networks which make up the abutment. Unless these are wake networks this will produce a discontinuity in doublet strength across these edges and will give rise to a line vortex. If this message is printed for the non-matching edges of wake networks, no user action is required. The doublet strength will be continuous across the edges. The continuity is imposed in this case by the wake type spline. The user should expect to see this message for every abutment which involves a network edge which the user has labelled as a "NO MATCHING" edge (see record N13 of section 7.4) as well as for all network edges which are "NON MATCHING" edges of wake networks and design networks.

```
INSUFFICIENT NUMBER OF CORNER POINTS ASSIGNED
TO IMPOSE DOUBLET MATCHING
  INTERSECTION    8
    NUMBER ASSIGNED     0
    NUMBER REQUIRED     1
    WITH ABUTMENTS
   1001  1002
```

At an abutment intersection a certain number of corner control points must be used to impose doublet continuity at the intersection. If this warning appears, it means that doublet strength will not be continuous at the indicated intersection unless it is an intersection which involves abutments with non-matching edges of wake networks. The list of abutment indices corresponds to the indices of network edge abutments if the indices lie between 1 and 999. If the indices lie between 1001 and 1999, they correspond to empty space abutments with indices between 1 and 999. If the indices are greater than 2000, (say 2XXX), they correspond to network edge abutments XXX (which include a plane of symmetry). The abutments in the list should include either non-matching edges of wake networks or network edges which the user has labelled as "NO MATCHING" edges. If the indicated abutments do not include such edges, then this may be a program error.

Table 8.18 - Warning messages in DQG overlay (4,0)

"4,0 OVERLY ELAPSED CPU TIME ..."

POOR LEAST SQUARES FIT

NETWORK WING-TIP
LATTICE INDEX-X 7
LATTICE INDEX-Y 5
DEVIATION FROM UNITY 5.369E-07

An ill-conditioned outer spline matrix was encountered. The user should expect the doublet spline in the vicinity of this point to be inaccurate. The lattice indices are the fine grid column and row indices of the point where the spline is evaluated. If an exotic panelling scheme has been employed, it is recommended that the user try a more conventional panelling scheme. It is possible that some coordinates of corner points in the vicinity of this point are mispunched. Also, a triangular design network (which is not permitted) may cause this error.

The solution should be accurate overall, but the solution in the vicinity of this point will be less reliable.

Table 8.19 - Warning messages in DQG overlay (5,0)

"5,0 OVERLY ELAPSED CPU TIME ..."

```
CRITICALLY INCLINED PANEL DISCOVERED
    NETWORK  UPPER-PLATE
     PANEL COLUMN      3
     PANEL ROW         6
       ANGLE WITH RESPECT TO MACH CONE  =  -3.017E-03


CRITICALLY INCLINED SUBPANEL DISCOVERED
    NETWORK BLUNT-TAIL
      PANEL COLUMN   6
      PANEL ROW      5
      SUBPANEL INDEX     1
        ANGLE WITH RESPECT TO MACH CONE  =  -3.796E-04
```

The solution near this panel or subpanel may be erroneous. Moreover it may have a bad effect on all panels downstream of it. A solution will be attempted, however. To avoid this difficulty change the Mach number or the geometry of the panel so that $\hat{n} \cdot \tilde{n} \neq 0$.

```
NON CONVEX PANEL DISCOVERED
    NETWORK  LOWER-PLATE
      PANEL COLUMN      7
      PANEL ROW         4


NEARLY NON CONVEX PANEL DISCOVERED
    NETWORK   LOWER-WING-TIP
      PANEL COLUMN      5
      PANEL ROW         9
```

Non-convex panels are permissible in PAN AIR (see section B.1.3). No difficulties should be expected. However, often an erroneous entry of network corner point coordinates gives rise to non-convex panels. If the user does not expect non-convex panels, he should check the coordinates of the network in the vicinity of the indicated panel.

Nearly non-convex panels may lead to singular subpanel spline matrices. If this should occur it is a fatal error. See table 8.14.

```
GAP SIZE EXCEEDS PANEL SIZE
    NETWORK BODY
    EDGE       1
    PANEL INDEX ALONG EDGE      9
     GAP SIZE/PANEL SIZE  =  3.691E 00
```

Unless inhibited by the user (see record G7 of section 7.3) gap filling panels will be added to fill in this excessive gap size. No user action is suggested.

Table 8.20 - Warning messages in DQG overlay (6,0)

| Error Code | Explanation |
|---|---|
| 5 | Permanent File Error. See table 8.22 for NOS 1.2 and 1.3 operating systems and see table 8.23 for SCOPE 2.1 and NOW/BE operating systems. |
| 6 | System error. System error 2 is the only user caused error which might occur. This means a premature end of information was encountered on a database file (i.e., the file is empty). The recommended user action is to assure that the database file is present. |
| 7 | Field length limit exceeded. Recommended user action is to increase field length appropriately to allow execution to proceed. |
| 11 | Unknown database name. Recommended user action is to correct misspelled database name in MEC input. |
| 22 | Attempting access which violates user password. Recommended user action is to find correct password for MEC input and rerun the job. |
| 28 | Duplicate database name. Recommended user action is to change the MEC directives which define the database name or purge the preexisting database file which has the same name. |

Table 8.21 - SDMS errors caused by user or operating system

| *Secondary Error Code | Explanation |
|---|---|
| 2 | One of the following has occurred: The specified permanent file could not be found. The specified account number could not be found. The user is not allowed to access the specified file. An indirect access file command was issued for a direct access file.<br><br>Recommended user action is to correct what is probably a misspelling of file name or account name in the MEC input deck. |
| 5 | The user has already saved or defined a file with the name specified. The user should either rename the file in the MEC input deck or should purge the preexisting file and rerun the job. |
| 7 | File name contains illegal characters. Correct the misspelled file name in the MEC input deck. |
| 8 | The user is not validated to create direct access or indirect access permanent files. Take whatever steps are required to gain validation permission before trying to rerun the job. |
| 9 | File length exceeds the limit for which the user is validated. Either obtain permission for generation of longer files or run a smaller sized problem. |
| 12 | Access to the permanent file device requested is not possible. This is an operating system difficulty. Consult with representatives of the computer system to determine when access will be available. |
| 16 | The number of files in the user's catalog exceeds the limit. Purge some of your files or obtain permission for a larger number of files. |
| 17 | The size of the indirect access files in the user's catalog exceeds the limit. Run a smaller job or obtain a greater limit on the size of your files. |

* ERROR is 5,N where N = Secondary error code

*Table 8.22 - Permanent file SDMS errors in the NOS 1.2 and NOS 1.3 operating systems*

| Secondary Error Code | Explanation |
|---|---|
| 20 | The job's local file limit has been exceeded. If the user is trying to save all database files, then either the user must obtain permission for a larger file limit or he must purge some local files as execution proceeds. |
| 21 | The job's mass storage physical record unit limit has been exceeded. Try running a smaller job or obtain a large limit for the mass storage physical record unit limit. |
| 22 | Permit limit has been exceeded for a private file. Take whatever steps are required to obtain permission to access the indicated file. |
| 24 | The resource executive has detected a fatal error. Consult with representatives of the computer system to determine the cause of the failure. The user might try to resubmit the job again. This is an operating system error. |
| 25 | No allocatable tracks remain on the equipment. The disk is full. Either run a smaller job or arrange to have access to a greater amount of space on the disk. This is often an unpredictable situation. Often rerunning the job will allow execution to continue particularly if the job is run during a time when demand for computer resources is low. |
| 31 | An error was encountered in reading a portion of the permanent file catalog or permit information. This is an operating system error. Consult with representatives of the computer system to determine the source of the problem and take whatever steps are required to fix the problem. |

Table 8.22 - Concluded

| *Secondary Error Code | Explanation |
|---|---|
| 4 | No room for new cycle. Purge previous cycles of files or rename database file in MEC input. |
| 10 | File not on set. Check for misspelled file name. If name is not misspelled, then file was inadvertantly purged. Recreate file and try job again. |
| 19 | Cycle incomplete on an attach. Recover detected error on file. This is an operating system error. The removable disk may need maintenance or replacement. |
| 22 | I/O error in permanent file device. Invalid extend. This is an operating system error. Try resubmitting job. |
| 29 | Permanent file already in system. Change name of file and try running the job again. |
| 32 | Illegal setname (set not mounted). Add appropriate mount commands to deck or correct misspelled setname in MEC input. |

* ERROR is 5,N where N = Secondary error code

Table 8.23 - SDMS permanent file error on AMES and WRIGHT operating systems

| Dataset Name | Contents |
|---|---|
| DATA-BASE-HEADER | Contains module name, version, condition, date, run ID, problem ID and user ID |
| GLOBAL | Global flow properties |
| GLOBAL-FLOW-PROP | Case counts and case labels for PDP and CDP problems |
| GLOLBAL-DB-OUTPUT | Count of PPP directives |
| GLOBAL-DEFAULTS | Global parameter values for use as default values in Network data as well as PDP and CDP problems |
| NETWORK-UPDATE-CODES | Update codes for all defined networks. Networks are fully updatable, edge updatable or not updatable |
| GLOBAL-PRINTS | Check print flags for each PAN AIR module |
| NETWK-SPEC | Specifications for each network, one dataset per network. Contains network parameters, boundary condition class, number of grid point rows and columns, singularity types, edge types, updatability and triangular panel tolerance |
| PANEL-COORDS | Array of grid points, one dataset per column, one set of columns per network |
| NETWORK-BDC | Network bulk data control data. Contains the count of terms and the identity of each term input for the five types of bulk data control data. One dataset per network. The five types are: closure, coefficient (general boundary condition equation), tangent vector, specified flow equation term, and local onset flow |

Table 8.24 - DIP datasets

| Dataset Name | Contents |
|---|---|
| CLOS-COND | Closure condition data, for a particular term, for a given network |
| COEFF-GEN-BC | Coefficient data, for a particular term, for a given network |
| TANG-VEC | Tangent vector data, for a particular term, for a given network |
| SPEC-FLOW | Specified flow data, for a particular term, for a given network |
| LOCAL-FLOW | Local onset flow, for a given network |
| USER-ABUT | User defined abutment data. One dataset per abutment. Contains list of networks in the abutment as well as the edge number and part of edge involved |
| SURF-FLOW | Surface flow properties for PDP problems. One dataset per case (problem). Contains list of networks, solutions and parameters to be saved or printed. |
| SURF-FAM | Surfaces, forces and moments for CDP problems. One dataset per case. Contains list of networks, solutions, and parameters to be saved or printed. |
| DB-OUTPNT | Data base output for PPP directives. One dataset per directive. |

Table 8.24 - Concluded

| Dataset Name | Contents |
|---|---|
| DATA-BASE-HEADER | Run identifier and data base condition |
| GLOBAL | Global flow properties |
| NETWK-SPEC | Network data |
| PANEL-CORNER-COORDS | Corner point coordinates |
| FINE-GRID-COORDS | Enriched grid coordinates |
| EDGE-POINT-COORDS | Coordinates of corner points at network edges |
| USER-ABUT | User-input abutment description |
| I-ABUT | Intermediate storage for automatic abutment search |
| SEARCH-LIST | |
| ABUTMENT-KEYS | |
| EXPANDED-ABUTMENT | |
| INTERSECTION | |
| ABUTMENT-SPEC | Abutment data (network edges) |
| EMPTY-SPACE-ABUT | Empty space abutment data |
| GAP-SIZE | Gap size for each panel on network edge |
| GAP-PANEL | Gap-filling panel data |
| SPECTAL-POINTS | Data for short and end points of abutments along network edges |
| BNDRY-CONDN-EN | User input boundary condition data (network wide) |
| CLASS-5-BC-DATA | User input boundary condition data (point by point) |
| CLOSURE-DATA-IN | User input closure data |
| CONTROL-PT-SPEC | Location and conormal of control point |

Table 8.25 - DQG datasets

| Dataset Name | Contents |
|---|---|
| BNDRY-CONDN-SPEC | Boundary condition data for control point |
| B-POINTER | Pointer for right-hand sides of boundary condition equations |
| EXTRA-HYPO-LOC | Extra hypothetical locations of matching control points |
| CLOSURE | Closure boundary condition data |
| PANEL-SPEC | Panel data: geometric, splines and far field moments |
| SINGULARITY-SPEC | Singularity parameter data (keyed by index) |
| SINGULARITY-MAP | Singularity parameter data (keyed by location in network) |
| B-SPLINE-SOURCE | Spline vector for source spline |
| B-SPLINE-DOUBLET | Spline vector for doublet spline |
| INTERIOR-SPLINE | Smooth abutment spline vector |

Table 8.25 - Concluded

| Dataset Name | Contents |
|---|---|
| DATA-BASE-HEADER | Run identification information |
| COLMAP | Singularity indices of DQG from MAG indices |
| COLMAP-INVERSE | Singularity indices of MAG from DQG indices |
| ROWMAP | Control point indices of DQG from MAG indices |
| ROWMAP-INVERSE | Control point indices of MAG from DQG indices |
| AIC-KNOWN (UNKNOWN) | AIC matrix partitions |
| SYMMETRY | Table of symmetrized matrices |
| IC-MATRICES | Influence coefficient matrices |

Table 8.26 - MAK datasets

---

| Dataset Name | Contents |
|---|---|
| DATA-BASE-HEADER | Data base header information consists of module, version, condition, date and run/problem/user identifications |
| PIVMAT | Pivot term information resulting from the decomposition process |
| BLIN | Matrix blocking information with the maximum number of column/row of blocks being set to 100 each (requires 214 words) |
| AICBLK | The AIC blocks of submatrices are stored in blank common (preset to 10,000 words) which must hold any 3 submatrices. A matrix of order 2000 by 2000 would have 36 row/column blocks with 57 rows/columns each stored on the data base |

Table 8.27 - RMS datasets

| Dataset Name | Contents |
|---|---|
| DATA-BASE-HEADER | Run identification information |
| SOLUTION-DATA | Solution and symmetry information |
| RHS-UNKNOWN | Equality constraints corresponding to unknown AIC elements |
| RHS-UPDATED | Equality constraints corresponding to known singularities |
| RHS-KNOWN | Equality constraints corresponding to unknown singularities |
| ONSET-FLOW | Flow vector at each control point |
| AIC-DIAGONAL | Known AIC elements in column form |
| LAMBDA-KNOWN | Known singularities in column form |
| LABMDA-UNKNOWN | Unknown singularities in column form |
| SING-KNOWN | Known singularities in row form |
| BLOCK-INFO | Blocking information |
| LAM-MAT | Blocked submatrices |

Table 8.28 - RHS datasets

| Dataset Name | Contents |
|---|---|
| DATA-BASES-HEADER | Run IDS, data base condition |
| GLOBAL | Global flow properties |
| NETWORK-SPEC | Network data |
| SOLUTION-DATA | Solution ID's and numbers |
| CP-GEOM | Control point data, normal, tangent vector and subpanel spline |
| GP-GEOM | Grid point coordinates, skewness parameter, doublet strength moment, doublet far field moment and normal cross product of doublet strength |
| CP-DATA | Control point data, control point index, singularities, average potential, mass flux and velocity X, Y, Z components at control point |
| GP-DATA | Grid point data, grid point sequence, singularities, average potential, mass flux and velocity X, Y, Z components at grid points |

Table 8.29 - MDG datasets

| Dataset Name | Contents |
|---|---|
| DATA-BASE-HEADER | Run, problem and user identification and condition of data base |
| GLOBAL | Number of cases, user options, network list, Mach number, compressibility direction, flow velocity, and symmetry information |
| NETWK-SPEC | Number of panel rows and columns plus the network source and singularity type information |
| SURF-OPTIONS | User options keyed by case number. The options include velocity correction, pressure rules and computed flow quantities |
| FLOW-QUANT | Surface flow quantities (pressure coefficients, local Mach numbers, mass flux, velocities, etc.) |

Table 8.30 - PDP datasets

| Dataset Name | Contents |
|---|---|
| DATA-BASE-HEADER | Run, problem and user identification and condition of data base |
| NETWK-SPEC | Number of panel rows and columns plus the network source and singularity type information |
| SURF-FAM-OPTIONS | User option data keyed by case number. The options include velocity correction type, velocity type, pressure rules, axis selection and accumulation rules |
| PANEL-FORCES | Forces and moments for each panel and selected accumulated totals |
| LEADING-EDGE-FORCE | Forces and moments for each selected network edge and accumulated totals for the edges |
| NETWORK-FORCES | Forces and moments for each selected network and accumulated totals |
| CONFIG-FORCES | Total forces and moments for each configuration and for each case. Forces and moments for selected accumulated totals for all cases |

Table 8.31 - CDP datasets

The network panel corner points data along with its identification information is written onto a plot file (logical unit 9), as given below:

| Record Set(s) | Item | Columns | Description |
|---|---|---|---|
| 1 | DQG Plot Titles | | DQG Plot Title Information consisting of 4 lines of title information as follows: |
| | a) NETWORK GEOMETRY FROM DQG DATA BASE | 1-35 | DQG Title (Format 3A10,A5) |
| | b) Run ID | 1-72 | DQG Run Identification (RID). (Format 7A10,A2) |
| | c) Problem ID | 1-72 | DQG Problem Identification (PID). (Format 7A10,A2) |
| | d) User ID | 1-72 | DQG User Identification (UID). (Format 7A10,A2) |
| 2 | *START | 1-5 | Signifies start of data (Format A5) |
| 3 | $GLOBAL DATA | 1-12 | Global Data (see table 11-E.2 of Maintenance Document for details) |
| 4 | (DQG Run Id) | 1-28 | DQG Run Name Identification (Format A1, I3, 2I2, 2A10) (see section 11-E.3 of Maintenance Document). |
| 5 | (Geometry Data from DQG) | | Network Geometry corner points data X, Y and Z along with its identification data [ Format I4, 6X, 3(I4, 1X), 3(F12.6, 1X)] |
| | | 1-4 | Sequence Number |
| | | 5-10 | Blanks |
| | | 11-14 | Row Number |
| | | 15 | Blank |
| | | 16-19 | Column Number |
| | | 20 | Blank |
| | | 21-24 | Network Number |
| | | 25 | Blank |
| | | 26-37 | X-coordinate |
| | | 38 | Blank |
| | | 39-50 | Y-coordinate |
| | | 51 | Blank |
| | | 52-63 | Z-coordinate |
| | | 64 | Blank |
| | | | (Repeat record sets 4 and 5 above for each Network selected.) |
| 6 | *END | 1-4 | The last line of data contains *END to signify the end of DQG data (Format A4) |

Table 8.32 - Plot file format for geometry data

A description of the Global Data for DQG is written on the geometry plot file (logical unit 9) following record set 2 (i.e., *START descriptor record signifying the start of data).

| Record Set(s) | Record Subset(s) | Item(s) | Columns | Description | Format |
|---|---|---|---|---|---|
| 3 | | $GLOBAL DATA | 1-12 | Global Data | A12 |
| | 1 | DATE | 1-5 | The heading DATA | A5 |
| | | DATECR | 6-15 | Date of creation in the form Yr/Mo/Date* | A10 |
| | 2 | AMACH | 1-10 | Mach Number | F10.5 |
| | | CALPHA | 11-20 | Angle of attack (degrees) | F10.5 |
| | | CBETA | 21-30 | Angle of sideslip (degrees) | F10.5 |
| | | NUMPOS | 31-35 | Number of planes of symmetry, =0 unsymmetric =1 one plane of sym. =2 two planes of sym. | I5 |
| | | NNET | 36-40 | Number of Networks | I5 |
| | 3 | POSNRM | 1-60 | Normal to first and second planes normal to the planes of symmetry (3 by NUMPOS) | 6F10.5 |
| | 4 | POSLOC | 1-30 | Coordinates of point common to first and second planes | 3F10.5 |
| | 5 | NETPPP,NETID | 1-70 | Network index and ID, two networks per record subset [network number (I4) and network id (2A10)] | 2(I4,1X,2A10,10X) |

* For the Ames system the form is Date/Mo/Yr

Table 8.33 - Global data for geometry file

| ITEM NUMBERS | COLUMNS | LITERAL NAME/VALUE | FORMAT | DESCRIPTION |
|---|---|---|---|---|
| 1 | 1 | D | A1 | DQG Identification |
| 2 | 2-4 | | I3 | Network Number |
| 3 | 5-6 | | I2 | Number of Rows |
| 4 | 7-8 | | I2 | Number of Columns |
| 5 | 9-28 | | A20 | Network ID |

Table 8.34 - DQG run name format

The format of the point data plot file (on logical unit 10) is described below:

| Record Set(s) | Item | Columns | Description |
|---|---|---|---|
| 1 | (6F10.5) 1-8 | | Data Format Specification (Format A8) |
| 2 | PDP PLOT TITLE(S) | | PDP Plot Title Information. Starts in column 1 with a $ and consists of 4 lines of title information as follows: |
| | a) $POINT DATA FROM PDP DATA BASE | 1-30 | PDP Plot Title (Format 3A10) |
| | b) $(RID) | 1-72 | PDP Run Identification (RID).(Format 7A10, A2) |
| | c) $(PID) | 1-72 | PDP Problem Identification (PID).(Format 7A10, A2) |
| | d) $(UID) | 1-72 | PDP User Identification (UID).(Format 7A10,A2) |
| 3 | *RUN 40 | 1-7 | Identifies maximum run name length of 40 alphanumeric characters in PDP run name (record set 6). |
| 4 | $GLOBAL DATA | 1-12 | Global Data (see table 8.36 for details) |
| 5 | (PDP Parameter Name List) | 1-76 | Identifies parameters available for plotting. If more than one line is needed to specify parameters, the word MORE must be entered in columns 73-76 on that line except for the last line of a parameter list. The parameter name list is written on the plot file at the beginning of each solution. The parameter list is written 6 per line. |
| 6 | (PDP Run Name) | 1-40 | A detailed description of the PDP run name is described in table 8.37 (Format A1, I2, I3, I2, 4A4, A1, I3, A3, A4, A1, I2, 2X). |
| 7 | (Point data from PDP in order of Parameter name list) | 1-60 | PDP Data list in order of parameter name list in the format specified in Record Set 1 above.<br><br>(Repeat Record Sets 6 and 7 above for all selected data options.) |
| 8 | *EOF | 1-4 | The last line of dataset contains *EOF to signify the end of data for that run (Format A4). |

Table 8.35 - Plot file format for point data

A description of the Global Data for PDP is written on the point data plot file (logical unit 10) following record set 3 (i.e., *RUN 40 descriptor record identifying maximum run name length of 40).

| Record Set(s) | Record Subset(s) | Item(s) | Columns | Description | Format |
|---|---|---|---|---|---|
| 4 | | $GLOBAL DATA | 1-12 | Global Data | A12 |
| | 1 | DATE | 1-5 | The heading DATA | A5 |
| | | DATECR | 6-15 | Date of creation in the form Yr/Mo/Date* | A10 |
| | 2 | AMACH | 1-10 | Mach Number | F10.5 |
| | | CALPHA | 11-20 | Angle of attack (degrees) | F10.5 |
| | | CBETA | 21-30 | Angle of sideslip (degrees) | F10.5 |
| | | NUMPOS | 31-35 | Number of planes of symmetry, =0 unsymmetric =1 one plane of sym. =2 two planes of sym. | I5 |
| | | NNET | 36-40 | Number of Networks | I5 |
| | | NSOL | 41-45 | Number of solutions | I5 |
| | | NCASE | 46-50 | Number of cases | I5 |
| | 3 | POSNRM | 1-60 | Normal to first and second planes normal to the planes of symmetry (3 by NUMPOS) | 6F10.5 |
| | 4 | POSLOC | 1-30 | Coordinates of point common to first and second planes | 3F10.5 |
| | 5 | NETPPP,NETID | 1-70 | Network index and ID, two networks per record subset [network number (I4) and network id (2A10)] | 2(I4,1X,2A10,10X) |
| | 6 | ALPHA | 1-70 | Angle of attack for each solution (max 200) | 7F10.5 |

* For the Ames system the form is Date/Mo/Yr

Table 8.36 - Global data for PDP file

| Record Set(s) | Record Subset(s) | Item(s) | Columns | Description | Format |
|---|---|---|---|---|---|
| | 7 | BETA | 1-70 | Angle of sideslip for each solution (max 200) | 7F10.5 |
| | 8 | SOLLST,SOLID | 1-70 | Solution index and ID, two solutions per record subset [ solution number (I4) and solution id (2A10)] | 2(I4,1X,2A10,10X) |
| | 9 | CASLST,CASEID | 1-70 | Case index and ID, two cases per record subset [ case number (I4) and case id (2A10)] | 2(I4,1X,2A10,10X) |

Table 8.36 - Concluded

| Item Number | Columns | Literal Name(s) or Value(s) | For Literal name or Associated Integer Format* | Description |
|---|---|---|---|---|
| 1 | 1 | P | A1 | PDP Identification |
| 2 (a) | 2-3 | | I2 | Case Number |
| (b) | 4-6 | | I3 | Solution Number |
| 3 | 7-8 | 99 | I2 | Job number, preset to 99 (not used) |
| 4 | 9-12 | UPPE - 1<br>LOWE - 2<br>UPLO - 3<br>LOUP - 4<br>AVER - 5 | A4/I4 | Surface Selection |
| 5 | 13-16 | BOUN - 1<br>VIC - 2 | A4/I4 | Velocity computation option |
| 6 | 17-20 | UNIF - 1<br>LOCA - 2 | A4/I4 | Pressure computation option |
| 7 | 21-24 | NONE - 0<br>SA1 - 1<br>SA2 - 2 | A4/I4 | Velocity correction option |
| 8 (a) | 25 | N | A1 | Network ID |
| (b) | 26-28 | | I3 | Network number |
| 9 | 29-31 | INP - 1<br>IST - 2<br>2ND - 3<br>3RD - 4 | A3/I3 | Images |
| 10 | 32-35 | CENT - 1<br>EDGE - 2<br>ADDI - 3<br>GRID - 4 | A4/I4 | Point type |
| 11(a) | 36 | R or C | A1 | Row or Column ID |
| (b) | 37-38 | | I2 | Row or Column Number |
| 12*(a) | 39 | C | A1 | Column ID |
| (b) | 40-41 | | I2 | Column Number |
| 13* | 42-44 | | I3 | Run Sequence Number |

* Note that the PDP plot file has 2 similar names for each dataset option. Item numbers 12 and 13 in the Run Name are used for only the second run name descriptive with associated integer values for item numbers 4, 5, 6, 7, 9 and 10 above. Also, the second run name length is 44 characters instead of the maximum length of 40 specified in record set 3 described in table 8.35.

Table 8.37 - PDP run name format

The format of the configuration data plot file on logical unit 11 is described below:

| Record Sets(s) | Item | Columns | Description |
|---|---|---|---|
| 1 | (6F10.5) | 1-8 | Data Format Specification (Format A8) |
| 2 | CDP Plot Title(s) | | CDP Plot Title Information. Starts in column with a $ and consists of 4 lines of title information as follows: |
| | a)$CONFIGURATION DATA FROM CDP DATA BASE | 1-38 | CDP Plot Title (Format 3A10, A8) |
| | b) $(RID) | 1-72 | CDP Run Identification (RID).(Format 7A10,A2) |
| | c) $(PID) | 1-72 | CDP Problem Identification (PID).(Format 7A10,A2) |
| | d) $(UID) | 1-72 | CDP User Identification (UID).(Format 7A10,A2) |
| 3 | *RUN 40 | 1-7 | Identifies maximum run name length of 40 alphanumeric characters in CDP run name (record set 6). |
| 4 | $GLOBAL DATA | 1-12 | Global Data (see table 8.39 for details) |
| 5 | (CDP Parameter Name List) | 1-76 | Identifies parameters available for plotting. If more than one line is needed to specify parameters, the word MORE must be entered in columns 73-76 on that line except for the last line of a parameter list. The CDP parameter name list is written on the plot file at the beginning of the plot file data for each solution and at the beginning of the accumulation sum data. The parameter list is written 6 per line. |
| 6 | (CDP Run Name) | 1-40 | A detailed description of the CDP Run Name is described in section 11-G.3 of Maintenance Document (Format A1, **, I2, 4A4, A1, I3, A3, A1, A1, I2, A1, I2, 2X). |

Table 8.38 - Plot file format for configuration data

| Record Sets(s) | Item | Columns | Description |
|---|---|---|---|
| 7 | (Configuration data from CDP in order of parameter name list) | 1-60 | CDP data is written in order of parameter name list specified in record set 5 above. The first record lists the solution number, magnitude of uniform onset flow velocity, alpha (angle of attack) and beta (angle of sideslip) values using format (I10, 3F10.5). The forces and moments data for the selected pressure rules and axis systems as shown in table 11.3 of Maintenance Document are written on the plot file in the format specified in record set 1 above.<br><br>(Repeat record sets 6 and 7 above for all selected data options.) |
| 8 | *EOF | 1-4 | The last line of dataset contains *EOF to signify the end of data for that run (Format A4). |

**Formats for configuration options in columns 2-6 of the CDP Run Name are described in table 8.40 item number 2.

Table 8.38 - Concluded

A description of the Global Data for CDP is written on the configuration data plot file (logical unit 11) following record set 3 (i.e., *RUN.40 descriptor record identifying maximum run name length of 40).

| Record Set(s) | Record Subset(s) | Item(s) | Columns | Description | Format |
|---|---|---|---|---|---|
| 4 | | $GLOBAL DATA | 1-12 | Global Data | A12 |
| | 1 | DATE | 1-5 | The heading DATA | A5 |
| | | DATECR | 6-15 | Date of creation in the form Yr/Mo/Date* | A10 |
| | 2 | AMACH | 1-10 | Mach number | F10.5 |
| | | CALPHA | 11-20 | Angle of attack (degrees) | F10.5 |
| | | CBETA | 21-30 | Angle of sideslip (degrees) | F10.5 |
| | | NUMPOS | 31-35 | Number of planes of symmetry, 0= unsymmetric 1= one plane of sym. 2= two planes of sym. | I5 |
| | | NNET | 36-40 | Number of networks | I5 |
| | | NSOL | 41-45 | Number of solutions | I5 |
| | | NCASE | 46-50 | Number of cases | I5 |
| | 3 | POSNRM | 1-60 | Normal to first and second planes normal to the planes of symmetry (3 by NUMPOS) | 6F10.5 |
| | 4 | POSLOC | 1-30 | Coordinates of point common to first and second planes | 3F10.5 |
| | 5 | NETPPP,NETID | 1-70 | Network index and ID, two networks per record subset [network number (I4) and network id (2A10)] | 2(I4,1X,2A10,10X) |
| | 6 | ALPHA | 1-70 | Angle of attack for each solution (max 200) | 7F10.5 |

* For the Ames system the form is Date/Mo/Yr

Table 8.39 - Global data for CDP file

| Record Set(s) | Record Subset(s) | Item(s) | Columns | Description | Format |
|---|---|---|---|---|---|
| | 7 | BETA | 1-70 | Angle of sideslip for each solution (max 200) | 7F10.5 |
| | 8 | SOLLST,SOLID | 1-70 | Solution index and ID, two solutions per record subset [ solution number (I4) and solution ID (2A10)] | 2(I4,1X,2A10,10X) |
| | 9 | CASLST,CASEID | 1-70 | Case index and ID, two cases per record subset [ case number (I4) and case ID (2A10)] | 2(I4,1X,2A10,10X) |
| | 10 | REFPAR | | List of reference data coefficient values | |
| | | SR | 1-10 | Area reference parameter | F10.5 |
| | | CR | 11-20 | Chord reference parameter | F10.5 |
| | | BR | 21-30 | Span reference parameter | F10.5 |
| | 11 | NUMAXS | 1-4 | Number of axis systems selected | I4 |
| | | AXISAR | | List of selected axis systems allowable | |
| | | | 5-8 | 1= reference coordinate system (RCS) | I4 |
| | | | 9-12 | 2= wind axis system (WAS) | I4 |
| | | | 13-16 | 3= body axis system (BAS) | I4 |
| | | | 17-20 | 4= stability axis system (SAS) | I4 |
| | 12 | MOMLST | 1-72 | Coordinates of moment reference values for above axis system (3 by NUMAXS) | 12F6.2 |
| | 13 | ELRLST | 1-72 | Euler angles in degrees to go from RCS to selected axis system only for BAS | 12F6.2 |

Table 8.39 - Concluded

| Item Numbers | Column(s) | Literal Name(s) | Format | Description |
|---|---|---|---|---|
| 1 | 1 | C | A1 | CDP Identification |
| 2(a)Panel | 2-3 | | I2 | Network Number |
| Data | 4-6 | | I3 | Panel Number |
| (b)Column | 2-3 | | I2 | Network Number |
| Sum | 4 | C | A1 | Column Sum ID |
| | 5-6 | | I2 | Column Number |
| (c)Network | 2-3 | | I2 | Network Number |
| Sum | 4-6 | | 3X | Blanks |
| (d)Config. | 2-4 | CON | A3 | Configuration ID |
| Sum | 5-6 | | I2 | Case Number |
| (e)Accum. | 2-4 | ACC | A3 | Accumulation ID |
| Sum | 5-6 | | I2 | Case Number |
| 3 | 7-8 | 99 | I2 | Job number, Preset to 99 (Not used) |
| 4 | 9-12 | UPPE<br>LOWE<br>UPLO<br>LOUP<br>AVER | A4 | Surface Selection Option |
| 5 | 13-16 | BOUN<br>VIC | A4 | Velocity Computation Option |
| 6 | 17-20 | UNIF<br>LOCA | A4 | Pressure Computation Option |
| 7 | 21-24 | NONE<br>SA1<br>SA2 | A4 | Velocity Correction Option |
| 8(a) | 25 | C | A1 | Case ID |
| (b) | 26-28 | | I3 | Case Number |
| 9 | 29-31 | INP<br>1ST<br>2ND<br>3RD | A3 | Images |
| 10(a) | 32 | P | A1 | Panel ID |
| (b) | 33 | R | A1 | Row ID |
| (c) | 34-35 | | I2 | Row Number |
| 11(a) | 36 | C | A1 | Column ID |
| (b) | 37-38 | | I2 | Column Number |

Table 8.40 - CDP run name format

```
**************************************************
*                                                *
*  PROGRAM MEC     VERSION D05        NOW RUNNING.  *
*  THE PROGRAM IS PART OF THE PAN AIR SYSTEM      *
*  DATE OF RUN IS  05/16/80                       *
*  TIME OF RUN IS  09.59.27                       *
*                                                *
**************************************************

INPUT RECORD    1 ....PAN AIR DIRECTIVES                                    .... CARD    1 (  1 )
INPUT RECORD    2 ....RID   PAN AIR INSTALLATION CASE 1 FOR SAMPLE OUTPUT   .... CARD    2 (  1 )
INPUT RECORD    3 ....SYSTEM PANAIR FAEBRP3 AMES                            .... CARD    3 (  1 )
INPUT RECORD    4 ....DATA BASE DIRECTIVE BLOCK                             .... CARD    4 (  1 )
INPUT RECORD    5 ....APPEND IC1 TO ALL                                     .... CARD    5 (  1 )
INPUT RECORD    6 ....UID = PANAIR FOR ALL                                  .... CARD    6 (  1 )
INPUT RECORD    7 ....MUID = PANAIR FOR ALL                                 .... CARD    7 (  1 )
INPUT RECORD    8 ....SET = FAEBRP3 FOR ALL                                 .... CARD    8 (  1 )
INPUT RECORD    9 ....MSET = FAEBRP3 FOR ALL                                .... CARD    9 (  1 )
INPUT RECORD   10 ....END DATA BASE DIRECTIVE BLOCK                         .... CARD   10 (  1 )
INPUT RECORD   11 ....END PAN AIR DIRECTIVES                                .... CARD   11 (  1 )
```

Figure 8.1 - Sample MEC output

```
PERMANENT DATA BASES TO BE USED DURING
THE PAN AIR RUN DATED  05/16/80
WITH THE RUN ID OF (   PAN AIR INSTALLATION CASE 1 FOR SAMPLE OUTPUT /

DEFAULT   ACTUAL SET-NAME
NAME      NAME   USER-NO     USER-ID     PASSWORD   PERM/TEMP  EXISTING    USED SAVED
-------   ------ ---------- ---------- ---------- ---------- ---------- ----- -----

DIP       DIPIC1 FAEBRP3     PANAIR      0          PERMANENT  0           0    0
      MD  DIPMD  FAEBRP3     PANAIR

DQG       DQGIC1 FAEBRP3     PANAIR      0          PERMANENT  0           0    0
      MD  DQGMD  FAEBRP3     PANAIR

MAK       MAKIC1 FAEBRP3     PANAIR      0          PERMANENT  0           0    0
      MD  MAKMD  FAEBRP3     PANAIR

MAU       MAUIC1 FAEBRP3     PANAIR      0          PERMANENT  0           0    0
      MD  MAUMD  FAEBRP3     PANAIR

MIC       MICIC1 FAEBRP3     PANAIR      0          PERMANENT  0           0    0
      MD  MICMD  FAEBRP3     PANAIR

RMS       RMSIC1 FAEBRP3     PANAIR      0          PERMANENT  0           0    0
      MD  RMSMD  FAEBRP3     PANAIR

RHS       RHSIC1 FAEBRP3     PANAIR      0          PERMANENT  0           0    0
      MD  RHSMD  FAEBRP3     PANAIR

MDG       MDGIC1 FAEBRP3     PANAIR      0          PERMANENT  0           0    0
      MD  MDGMD  FAEBRP3     PANAIR

PDP       PDPIC1 FAEBRP3     PANAIR      0          PERMANENT  0           0    0
      MD  PDPMD  FAEBRP3     PANAIR

CDP       CDPIC1 FAEBRP3     PANAIR      0          PERMANENT  0           0    0
      MD  CDPMD  FAEBRP3     PANAIR

OFH       OFHIC1 FAEBRP3     PANAIR      0          PERMANENT  0           0    0
      MD  OFHMD  FAEBRP3     PANAIR
```

Figure 8.1 - Continued

```
TEMPORARY DATA BASES TO BE USED DURING
THE PAN AIR RUN DATED  05/16/80
WITH THE RUN ID OF (   PAN AIR INSTALLATION CASE 1 FOR SAMPLE OUTPUT /
```

| DEFAULT NAME | | ACTUAL NAME | SET-NAME USER-NO | USER-ID | PASSWORD | PERM/TEMP | EXISTING | USED | SAVED |
|---|---|---|---|---|---|---|---|---|---|
| MAGX | | MAGX | FAEBRP3 | PANAIR | 0 | TEMPORARY | 0 | 0 | 0 |
| | MD | MAGXMD | FAEBRP3 | PANAIR | | | | | |
| MAGY | | MAGY | FAEBRP3 | PANAIR | 0 | TEMPORARY | 0 | 0 | 0 |
| | MD | MAGYMD | FAEBRP3 | PANAIR | | | | | |
| MAGZ | | MAGZ | FAEBRP3 | PANAIR | 0 | TEMPORARY | 0 | 0 | 0 |
| | MD | MAGZMD | FAEBRP3 | PANAIR | | | | | |
| RMST | | RMST | FAEBRP3 | PANAIR | 0 | TEMPORARY | 0 | 0 | 0 |
| | MD | RMSTMD | FAEBRP3 | PANAIR | | | | | |
| RHSX | | RHSX | FAEBRP3 | PANAIR | 0 | TEMPORARY | 0 | 0 | 0 |
| | MD | RHSXMD | FAEBRP3 | PANAIR | | | | | |
| MDGF | | MDGF | FAEBRP3 | PANAIR | 0 | TEMPORARY | 0 | 0 | 0 |
| | MD | MDGFMD | FAEBRP3 | PANAIR | | | | | |
| MDGC | | MDGC | FAEBRP3 | PANAIR | 0 | TEMPORARY | 0 | 0 | 0 |
| | MD | MDGCMD | FAEBRP3 | PANAIR | | | | | |
| MDGM | | MDGM | FAEBRP3 | PANAIR | 0 | TEMPORARY | 0 | 0 | 0 |
| | MD | MDGMMD | FAEBRP3 | PANAIR | | | | | |
| PDPT | | PDPT | FAEBRP3 | PANAIR | 0 | TEMPORARY | 0 | 0 | 0 |
| | MD | PDPTMD | FAEBRP3 | PANAIR | | | | | |
| CDPT | | CDPT | FAEBRP3 | PANAIR | 0 | TEMPORARY | 0 | 0 | 0 |
| | MD | CDPTMD | FAEBRP3 | PANAIR | | | | | |
| OFBT | | OFBT | FAEBRP3 | PANAIR | 0 | TEMPORARY | 0 | 0 | 0 |
| | MD | OFBTMD | FAEBRP3 | PANAIR | | | | | |

**Figure 8.1 - Continued**

```
**************************************************
*                                                *
*   PROGRAM MEC     VERSION 005.       IS FINISHED.  *
*   DATE OF RUN IS  05/16/80                     *
*   TIME OF RUN IS  09.59.29                     *
*                                                *
**************************************************

    CP SECONDS USED BY MEC        =        .0800
```

Figure 8.1 - Concluded

```
*****************************************************
*                                                   *
*   PROGRAM DIP      VERSION 1.0        NOW RUNNING.  *
*   THE PROGRAM IS PART OF THE PAN AIR SYSTEM         *
*   DATE OF RUN IS  05/16/80                          *
*   TIME OF RUN IS  09.59.30                          *
*                                                   *
*****************************************************

INPUT RECORD     1 ....*/ PAN AIR CASE MANUAL CASE 1                                    .... CARD    1 (  1 )

INPUT RECORD     1 ....*/ 4 PANEL DELTA WING, WITH 2 PLANES OF SYMMETRY AND NO WAKE     .... CARD    2 (  1 )

INPUT RECORD     1 ....*/ SUPERSONIC FLOW, MACH NUMBER 2.0                              .... CARD    3 (  1 )

INPUT RECORD     1 ....*/  START GLOBAL DATA GROUP                                      .... CARD    4 (  1 )

INPUT RECORD     1 ....BEGIN GLOBAL DATA     /G1                                       .... CARD    5 (  1 )

    DATA BASES TO BE USED

    DEFAULT   ACTUAL
    NAME      NAME      LOCATION       GENERATED BY
    ------    ------    ------ ------  ------ ------ --------
    DIP       DIPIC1    FAEBRP3 PANAIR
          MD  DIPMD     FAEBRP3 PANAIR

INPUT RECORD     2 ....PID = SIMPLE DELTA WING WITH THICKNESS                           .... CARD    6 (  1 )

INPUT RECORD     3 ....UID=USER IDENTIFICATION                                          .... CARD    7 (  1 )

INPUT RECORD     4 ....MACH = 2.0  CALPHA = 0. CBETA = 0.     /G4                       .... CARD    8 (  1 )

INPUT RECORD     5 ....*/ TWO PLANES OF CONFIGURATION SYMMETRY                          .... CARD    9 (  1 )

INPUT RECORD     5 ....*/ FIRST-PLANE HAS DEFAULT OPTIONS --                            .... CARD   10 (  1 )

INPUT RECORD     5 ....*/ NORMAL VECTOR IS Y-AXIS                                       .... CARD   11 (  1 )

INPUT RECORD     5 ....*/ SYMMETRIC-FLOW (BETA MUST BE ZERO)                            .... CARD   12 (  1 )

INPUT RECORD     5 ....*/ SECOND-PLANE HAS ASYMMETRIC-FLOW, ALLOWING                    .... CARD   13 (  1 )

INPUT RECORD     5 ....*/ NON-ZERO VALUE OF ALPHA                                       .... CARD   14 (  1 )

INPUT RECORD     5 .... CONF = SECOND, 0. 0. 1.,ASYMMETRIC-FLOW   /G5                   .... CARD   15 (  1 )

INPUT RECORD     6 ....*/ USE DEFAULTS FOR ALL SOLUTION DATA EXCEPT ALPHA AND SOLUTION-ID .... CARD   16 (  1 )

INPUT RECORD     6 ....*/ (BETA = 0., UINF = 1., WM = 0. FOR ALL SOLUTIONS)             .... CARD   17 (  1 )

INPUT RECORD     6 ....ALPHA = -.57295,.0,+.57295 /G6.1                                 .... CARD   18 (  1 )

INPUT RECORD     7 .... SID = SOLN-1, SOLN-2, SOLN-3   /G6.2                            .... CARD   19 (  1 )

INPUT RECORD     8 ....PRESSURE COEFFICIENT RULES = ISEN SECOND REDUCED SLENDER LINEAR /G12 .... CARD   20 (  1 )

INPUT RECORD     9 ....CHECKOUT PRINTS = DIP 1 2 3, DBG 1 2 3 7 /G17                    .... CARD   21 (  1 )

INPUT RECORD    10 ....*/                                                               .... CARD   22 (  1 )
```

Figure 8.2 - Sample DIP output

```
INPUT RECORD   10 ....*/  START NETWORK DATA GROUP                          .... CARD   23 (  1 )
INPUT RECORD   10 ....BEGIN NETWORK DATA     /N1                           .... CARD   24 (  1 )
```



GLOBAL DATA

SUPERSONIC FLOW MACH NUMBER = 2.0000000

DIRECTION OF COMPRESSIBILITY

| ANGLE OF ATTACK | | ANGLE OF SIDESLIP | |
|---|---|---|---|
| DEG. | RAD. | DEG. | RAD. |
| 0.00 | 0.00 | 0.00 | 0.00 |

COMPRESSIBILITY VECTOR

1.00 0.00 0.00

SYMMETRY

| PLANE | DIRECTION NUMBERS | | | POINT | | | FLOW TYPE |
|---|---|---|---|---|---|---|---|
| FIRST | 0.00 | 1.00 | 0.00 | 0.00 | 0.00 | 0.00 | SYMMETRIC |
| SECOND | 0.00 | 0.00 | 1.00 | 0.00 | 0.00 | 0.00 | DECOMPOSITION |

SOLUTION DATA

| RHS SOL. NO. | RHS SOL. ID | ANGLE OF ATTACK | ANGLE OF SIDESLIP | MAGNITUDE OF ONSET FLOW | ROTATION MAGNITUDE | ROTATION VECTOR COMPONENTS | | | | ROTATION CENTER | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | SOLN-1 | -.5730 | 0.0000 | 1.0000 | 0.0000 | 0.000 | 0.000 | 0.000 | 0.00 | 0.00 | 0.00 | 0.00 |
| 2 | SOLN-2 | 0.0000 | 0.0000 | 1.0000 | 0.0000 | 0.000 | 0.000 | 0.000 | 0.00 | 0.00 | 0.00 | 0.00 |
| 3 | SOLN-3 | .5730 | 0.0000 | 1.0000 | 0.0000 | 0.000 | 0.000 | 0.000 | 0.00 | 0.00 | 0.00 | 0.00 |

```
INPUT RECORD   11 ....NETWORK=UPPER-WING, 3, 3, NEW  /N2A                                                  .... CARD   25 (  1 )
INPUT RECORD   12 ....  0.0000E-01  0.0000E-01  0.0000E-01  5.0000E-01  0.0000E-01  2.5000E-02              .... CARD   26 (  1 )
INPUT RECORD   13 ....  1.0000E+00  0.0000E-01  0.0000E-01  5.0000E-01  5.0000E-01  0.0000E-01              .... CARD   27 (  1 )
INPUT RECORD   14 ....  7.5000E-01  5.0000E-01  1.2500E-02  1.0000E+00  5.0000E-01  0.0000E-01              .... CARD   28 (  1 )
INPUT RECORD   15 ....  1.0000E+00  1.0000E+00  0.0000E-01  1.0000E+00  1.0000E+00  0.0000E-01              .... CARD   29 (  1 )
INPUT RECORD   16 ....  1.0000E+00  1.0000E+00  0.0000E-01                                                  .... CARD   30 (  1 )
INPUT RECORD   17 ....*/ NORMAL VECTORS POINT (NOMINALLY) DOWNWARD                                         .... CARD   31 (  1 )
INPUT RECORD   17 ....*/ NETWORK LOWER SURFACE EXPOSED TO EXTERNAL FLOW FIELD                              .... CARD   32 (  1 )
INPUT RECORD   17 ....*/ NETWORK EDGE 1-LEADING EDGE                                                       .... CARD   33 (  1 )
INPUT RECORD   17 ....*/ NETWORK EDGE 2-COLLAPSED WING TIP                                                 .... CARD   34 (  1 )
```

Figure 8.2 - Continued

```
INPUT RECORD   17 ....*/ NETWORK EDGE 3-TRAILING EDGE                          .... CARD   35 (  1 )
INPUT RECORD   17 ....*/ NETWORK EDGE 4-INBOARD EDGE                           .... CARD   36 (  1 )
INPUT RECORD   17 ....BOUNDARY CONDITION= 1,2  /N9                             .... CARD   37 (  1 )
INPUT RECORD   18 ....*/ REMOVE DOUBLET MATCHING CONDITION ON TRAILING EDGE    .... CARD   38 (  1 )
INPUT RECORD   18 ....NO DOUBLET MATCHING = 3  /N13                            .... CARD   39 (  1 )
INPUT RECORD   19 ....*/ WAKE OMITTED                                          .... CARD   40 (  1 )
INPUT RECORD   19 ....*/                                                       .... CARD   41 (  1 )
INPUT RECORD   19 ....*/  OMIT GEOMETRIC EDGE MATCHING DATA GROUP             .... CARD   42 (  1 )
INPUT RECORD   19 ....*/                                                       .... CARD   43 (  1 )
INPUT RECORD   19 ....*/  START FLOW PROPERTIES DATA GROUP                     .... CARD   44 (  1 )
INPUT RECORD   19 ....BEGIN FLOW PROPERTIES DATA  /FF1                         .... CARD   45 (  1 )
```

**Figure 8.2 - Continued**

NETWORK DATA

| NETWORK NO. | NETWORK ID | NETWORK STATUS | B.C. CLASS | B.C. SUBCLASS | SINGULARITY TYPES SA | SINGULARITY TYPES DA | POINT ROWS | POINT COLUMNS |
|---|---|---|---|---|---|---|---|---|
| 1 | UPPER-WING | NEW | 1 | 2 | | | 3 | 3 |

```
INPUT RECORD   20 ....*/  START SURFACE FLOW PROPERTIES DATA SUBGROUP                  .... CARD   46 (  1 )
INPUT RECORD   20 ....*/  SURFACE FLOW PROPERTIES CASE 1                              .... CARD   47 (  1 )
INPUT RECORD   20 ....SURFACE FLOW PROPERTIES=ZERO-ALPHA   /SF1                       .... CARD   48 (  1 )
INPUT RECORD   21 .... NETWORKS-IMAGES = 1, INPUT, 3RD  /SF2                         .... CARD   49 (  1 )
INPUT RECORD   22 ...., SOLUTIONS = 2  /SF3                                          .... CARD   50 (  1 )
INPUT RECORD   23 .... POINTS = ALL  /SF4                                            .... CARD   51 (  1 )
INPUT RECORD   24 ....SURFACES = UPPER, LOWER  /SF5                                  .... CARD   52 (  1 )
INPUT RECORD   25 .... PRINTOUT = ALL  /SF10A                                        .... CARD   53 (  1 )
INPUT RECORD   26 ....*/ GENERATE DATA BASE - TO BE SORTED BY PPP MODULE             .... CARD   54 (  1 )
INPUT RECORD   26 ....DATA BASE = ALL   /SF11A                                       .... CARD   55 (  1 )
INPUT RECORD   27 ....*/  SURFACE FLOW PROPERTIES CASE 2                            .... CARD   56 (  1 )
INPUT RECORD   27 ....SURFACE FLOW PROPERTIES=ALPHA-VARIATION-SF  /SF1               .... CARD   57 (  1 )
INPUT RECORD   28 .... NETWORKS-IMAGES = 1, INPUT, 1ST, 2ND, 3RD  /SF2               .... CARD   58 (  1 )
INPUT RECORD   29 ....*/ OMIT RECORD SF3, DEFAULT IS ALL SOLUTIONS                   .... CARD   59 (  1 )
INPUT RECORD   29 ....POINTS = CENTER  /SF4-DEFAULT                                  .... CARD   60 (  1 )
INPUT RECORD   30 ....SURFACES = UPPER, LOWER  /SF5                                  .... CARD   61 (  1 )
INPUT RECORD   31 .... PRINTOUT = ALL  /SF10A                                        .... CARD   62 (  1 )
INPUT RECORD   32 ....*/ GENERATE DATA BASE-TO BE SORTED BY PPP MODULE               .... CARD   63 (  1 )
INPUT RECORD   32 ....DATA BASE = ALL  /SF11A                                        .... CARD   64 (  1 )
INPUT RECORD   33 ....*/                                                             .... CARD   65 (  1 )
INPUT RECORD   33 ....*/  START FORCES AND MOMENTS DATA SUBGROUP                     .... CARD   66 (  1 )
INPUT RECORD   33 ....FORCES AND MOMENTS   /FM1                                      .... CARD   67 (  1 )
INPUT RECORD   34 .... SOLUTIONS = 1, 2, 3  /FM4-DEFAULT                             .... CARD   68 (  1 )
INPUT RECORD   35 .... PRINTOUT = ALL   /FM5                                         .... CARD   69 (  1 )
INPUT RECORD   36 ....*/ GENERATE DATA BASE-TO BE SORTED BY PPP MODULE               .... CARD   70 (  1 )
```

Figure 8.2 - Continued

```
INPUT RECORD   36 .... DATA BASE = ALL  /FM6                                  .... CARD   71 (  1 )
INPUT RECORD   37 ....*/ FORCES AND MOMENTS CASE 1                            .... CARD   72 (  1 )
INPUT RECORD   37 .... CASE = ALPHA-VARIATION-FM  /FM7                        .... CARD   73 (  1 )
INPUT RECORD   38 .... NETWORKS-IMAGES = 1, INPUT  /FM8                       .... CARD   74 (  1 )
INPUT RECORD   39 ....SURFACES = LOWER  /FM12                                 .... CARD   75 (  1 )
INPUT RECORD   40 ....*/ INCLUDE THIS CASE IN THE ACCUMULATION CASE,          .... CARD   76 (  1 )
INPUT RECORD   40 ....*/ AND SELECT ONE PRESSURE COEFFICIENT RULE             .... CARD   77 (  1 )
INPUT RECORD   40 .... ACCUMULATE = ISENTROPIC  /FM21                         .... CARD   78 (  1 )
INPUT RECORD   41 ....*/                                                      .... CARD   79 (  1 )
INPUT RECORD   41 ....*/  START PRINT PLOT DATA GROUP                        .... CARD   80 (  1 )
INPUT RECORD   41 ....BEGIN PRINT PLOT DATA  /PP1                             .... CARD   81 (  1 )
INPUT RECORD   42 .... GEOMETRY DATA  /PP2A                                   .... CARD   82 (  1 )
INPUT RECORD   43 .... POINT DATA /PP3A                                       .... CARD   83 (  1 )
INPUT RECORD   44 .... CASE = 2  /PP3B                                        .... CARD   84 (  1 )
INPUT RECORD   45 .... NETWORKS-IMAGES = 1, INPUT  /PP3D                      .... CARD   85 (  1 )
INPUT RECORD   46 .... CONFIGURATION DATA   /PP4A                             .... CARD   86 (  1 )
INPUT RECORD   47 .... NETWORKS-IMAGES = 1, INPUT, PANELS, COLSUM  /PP4D      .... CARD   87 (  1 )
INPUT RECORD   48 .... END PROBLEM DEFINITION                                 .... CARD   88 (  1 )
```

Figure 8.2 - Continued

```
**************************************************
*                                                *
*   PROGRAM DIP      VERSION 1.0        IS FINISHED.  *
*   DATE OF RUN IS  05/16/80                      *
*   TIME OF RUN IS  09.59.47                      *
*                                                *
**************************************************

    CP SECONDS USED BY DIP        =         .3450
```

Figure 8.2 - Concluded

```
**************************************************
*                                                *
*   PROGRAM DQG     VERSION A01        NOW RUNNING.  *
*   THE PROGRAM IS PART OF THE PAN AIR SYSTEM     *
*   DATE OF RUN IS  05/16/80                      *
*   TIME OF RUN IS  09.59.52                      *
*                                                *
**************************************************


0.0 OVERLY                    ELAPSED CPU TIME      .637


 DATA BASES TO BE USED

 DEFAULT   ACTUAL
 NAME      NAME      LOCATION       GENERATED BY
 -------   -------   -------- ------  ------- ------ --------
 DIP       DIPIC1    FAEBRP3 PANAIR
       MD  DIPMD     FAEBRP3 PANAIR
                                      DIP    1.0     05/16/80
                                      RID =   PAN AIR INSTALLATION CASE 1 FOR SAMPLE OUTPUT /
                                      PID =     = SIMPLE DELTA WING WITH THICKNESS
                                      UID =     USER IDENTIFICATION
 DQG       DQGIC1    FAEBRP3 PANAIR
       MD  DQGMD     FAEBRP3 PANAIR


1.0 OVERLY                    ELAPSED CPU TIME      .342
```

Figure 8.3 - Sample DQG output

PANEL CORNER POINT COORDINATES

| NETWORK-ID | ROW | COLUMN INDEX | | X VALUE | Y VALUE | Z VALUE | CHANGED |
|---|---|---|---|---|---|---|---|
| UPPER-WING | 1 | 1 | 1 | 0.0000 | 0.0000 | 0.0000 | |
| UPPER-WING | 2 | 1 | 2 | .5000 | 0.0000 | .0250 | |
| UPPER-WING | 3 | 1 | 3 | 1.0000 | 0.0000 | 0.0000 | |
| UPPER-WING | 1 | 2 | 4 | .5000 | .5000 | 0.0000 | |
| UPPER-WING | 2 | 2 | 5 | .7500 | .5000 | .0125 | |
| UPPER-WING | 3 | 2 | 6 | 1.0000 | .5000 | 0.0000 | |
| UPPER-WING | 1 | 3 | 7 | 1.0000 | 1.0000 | 0.0000 | CHANGED |
| UPPER-WING | 2 | 3 | 8 | 1.0000 | 1.0000 | 0.0000 | CHANGED |
| UPPER-WING | 3 | 3 | 9 | 1.0000 | 1.0000 | 0.0000 | CHANGED |

Figure 8.3 - Continued

ENRICHED PANEL CORNER POINT COORDINATES

| NETWORK-ID | ROW | COLUMN INDEX | | X VALUE | Y VALUE | Z VALUE |
|---|---|---|---|---|---|---|
| UPPER-WING | 1 | 1 | 1 | 0.0000 | 0.0000 | 0.0000 |
| UPPER-WING | 2 | 1 | 2 | .2500 | 0.0000 | .0125 |
| UPPER-WING | 3 | 1 | 3 | .5000 | 0.0000 | .0250 |
| UPPER-WING | 4 | 1 | 4 | .7500 | 0.0000 | .0125 |
| UPPER-WING | 5 | 1 | 5 | 1.0000 | 0.0000 | 0.0000 |
| UPPER-WING | 1 | 2 | 6 | .2500 | .2500 | 0.0000 |
| UPPER-WING | 2 | 2 | 7 | .4375 | .2500 | .0094 |
| UPPER-WING | 3 | 2 | 8 | .6250 | .2500 | .0188 |
| UPPER-WING | 4 | 2 | 9 | .8125 | .2500 | .0094 |
| UPPER-WING | 5 | 2 | 10 | 1.0000 | .2500 | 0.0000 |
| UPPER-WING | 1 | 3 | 11 | .5000 | .5000 | 0.0000 |
| UPPER-WING | 2 | 3 | 12 | .6250 | .5000 | .0063 |
| UPPER-WING | 3 | 3 | 13 | .7500 | .5000 | .0125 |
| UPPER-WING | 4 | 3 | 14 | .8750 | .5000 | .0063 |
| UPPER-WING | 5 | 3 | 15 | 1.0000 | .5000 | 0.0000 |
| UPPER-WING | 1 | 4 | 16 | .7500 | .7500 | 0.0000 |
| UPPER-WING | 2 | 4 | 17 | .8125 | .7500 | .0031 |
| UPPER-WING | 3 | 4 | 18 | .8750 | .7500 | .0063 |
| UPPER-WING | 4 | 4 | 19 | .9375 | .7500 | .0031 |
| UPPER-WING | 5 | 4 | 20 | 1.0000 | .7500 | 0.0000 |
| UPPER-WING | 1 | 5 | 21 | 1.0000 | 1.0000 | 0.0000 |
| UPPER-WING | 2 | 5 | 22 | 1.0000 | 1.0000 | 0.0000 |
| UPPER-WING | 3 | 5 | 23 | 1.0000 | 1.0000 | 0.0000 |
| UPPER-WING | 4 | 5 | 24 | 1.0000 | 1.0000 | 0.0000 |
| UPPER-WING | 5 | 5 | 25 | 1.0000 | 1.0000 | 0.0000 |

2,0 OVERLY ELAPSED CPU TIME .153

3,1 OVERLY ELAPSED CPU TIME .095

3,2 OVERLY ELAPSED CPU TIME .066

Figure 8.3 - Continued

```
3,3 OVERLY                    ELAPSED CPU TIME      .013


******** WARNING

         NO DOUBLET MATCHING AT NETWORK EDGE
           ABUTMENT INDEX      2

         NETWORK     EDGE     START-X     START-Y      END-X      END-Y
               1        3           1           3          3          3
              -2        0           0           0          0          0


******** WARNING

         INSUFFICIENT NUMBER OF CORNER POINTS ASSIGNED
         TO IMPOSE DOUBLET MATCHING.

         INTERSECTION NUMBER      1

         NUMBER ASSIGNED      0
         NUMBER REQUIRED      1
         WITH ABUTMENTS
           2002  2003


******** WARNING

         INSUFFICIENT NUMBER OF CORNER POINTS ASSIGNED
         TO IMPOSE DOUBLET MATCHING.

         INTERSECTION NUMBER      2

         NUMBER ASSIGNED      0
         NUMBER REQUIRED      1
         WITH ABUTMENTS
           2002  2001

3,4 OVERLY                    ELAPSED CPU TIME      .031
```

**Figure 8.3 - Continued**



```
3,6 OVERLY                    ELAPSED CPU TIME      .036
```

```
3,0 OVERLY              ELAPSED CPU TIME      .038

4,0 OVERLY              ELAPSED CPU TIME      .239

5,0 OVERLY              ELAPSED CPU TIME      .275

6,0 OVERLY              ELAPSED CPU TIME      .555
```

Figure 8.3 - Continued

DQG GLOBAL DATA SUMMARY

```
RUN IDENTIFIER
  PAN AIR INSTALLATION CASE 1 FOR SAMPLE OUTPUT /
USER IDENTIFIER
   = SIMPLE DELTA WING WITH THICKNESS
PROBLEM IDENTIFIER
   USER IDENTIFICATION
```

| RUN | MACH | COMPRESS | NMBR OF SINGULARITY PARAMETERS | NMBR OF CONTROL POINTS | NMBR OF BOUNDARY CONDITIONS | NMBR OF GAP FILL PANELS |
|---|---|---|---|---|---|---|
| INIT | 2.000E+00 | 1.000E+00<br>0.<br>0. | 20 | 16 | 17 | 0 |

| PLANE OF SYMMETRY | LOCATION | NORMAL |
|---|---|---|
| 1 | 0. | 0. |
| | 0. | 1.000E+00 |
| | 0. | 0. |
| 2 | 0. | 0. |
| | 0. | 0. |
| | 0. | 1.000E+00 |

| INDEX | NETWORK IDENTIFIER | UPDATE FLAG | NETWORK SIZE COL | NETWORK SIZE ROW | SOURCE/ DOUBLET TYPE | SOURCE EDGE TYPE | DOUBLET EDGE TYPE |
|---|---|---|---|---|---|---|---|
| 1 | UPPER-WING | NON | 3 | 3 | SA<br>DA | | NO |

Figure 8.3 - Continued

BOUNDARY CONDITION DATA
FOR
NETWORK UPPER-WING

| INDEX | LOCATION ROW | LOCATION COL | COEFFICIENTS OF NON-ZERO TERMS (FIRST SYMMETRY CONDITION ONLY) | | | |
|---|---|---|---|---|---|---|
| 1 | 2 | 2 | POT = | 1.000E+00 | DBLT = | 5.000E-01 |
| 1 | 2 | 2 | SRC = | 1.000E+00 | | |
| 2 | 4 | 2 | POT = | 1.000E+00 | DBLT = | 5.000E-01 |
| 2 | 4 | 2 | SRC = | 1.000E+00 | | |
| 3 | 2 | 4 | POT = | 1.000E+00 | DBLT = | 5.000E-01 |
| 3 | 2 | 4 | SRC = | 1.000E+00 | | |
| 4 | 4 | 4 | POT = | 1.000E+00 | DBLT = | 5.000E-01 |
| 4 | 4 | 4 | SRC = | 1.000E+00 | | |
| 6 | 1 | 2 | POT = | 1.000E+00 | DBLT = | 5.000E-01 |
| 6 | 1 | 2 | NULL | | | |
| 7 | 1 | 4 | POT = | 1.000E+00 | DBLT = | 5.000E-01 |
| 7 | 1 | 4 | NULL | | | |
| 9 | 2 | 5 | NULL | | | |
| 9 | 2 | 5 | NULL | | | |
| 10 | 4 | 5 | NULL | | | |
| 10 | 4 | 5 | NULL | | | |
| 12 | 5 | 4 | POT = | 1.000E+00 | DBLT = | 5.000E-01 |
| 12 | 5 | 4 | NULL | | | |
| 13 | 5 | 2 | POT = | 1.000E+00 | DBLT = | 5.000E-01 |
| 13 | 5 | 2 | NULL | | | |
| 15 | 4 | 1 | POT = | 1.000E+00 | DBLT = | 5.000E-01 |
| 15 | 4 | 1 | NULL | | | |
| 16 | 2 | 1 | POT = | 1.000E+00 | DBLT = | 5.000E-01 |
| 16 | 2 | 1 | NULL | | | |
| 5 | 1 | 1 | POT = | 1.000E+00 | DBLT = | 5.000E-01 |
| 5 | 1 | 1 | NULL | | | |
| 8 | 1 | 5 | POT = | 1.000E+00 | DBLT = | 5.000E-01 |

**Figure 8.3 - Continued**

```
  8     1       5  NULL

 11     5       5  NULL
 11     5       5  NULL
```

BOUNDARY CONDITION DATA
FOR
NETWORK UPPER-WING

| INDEX | LOCATION ROW | COL | COEFFICIENTS OF NON-ZERO TERMS (FIRST SYMMETRY CONDITION ONLY) |
|---|---|---|---|
| 14 | 5 | 1 | POT = 1.000E+00 DBLT = 5.000E-01 |
| 14 | 5 | 1 | NULL |

```
7.0 OVERLY                    ELAPSED CPU TIME       .132
```

Figure 8.3 - Continued

```
**************************************************
*                                                *
*   PROGRAM DQG     VERSION A01       IS FINISHED. *
*   DATE OF RUN IS  05/16/80                       *
*   TIME OF RUN IS  10.01.26                       *
*                                                *
**************************************************

    CP SECONDS USED BY DQG        =       1.9990
```

Figure 8.3 - Concluded

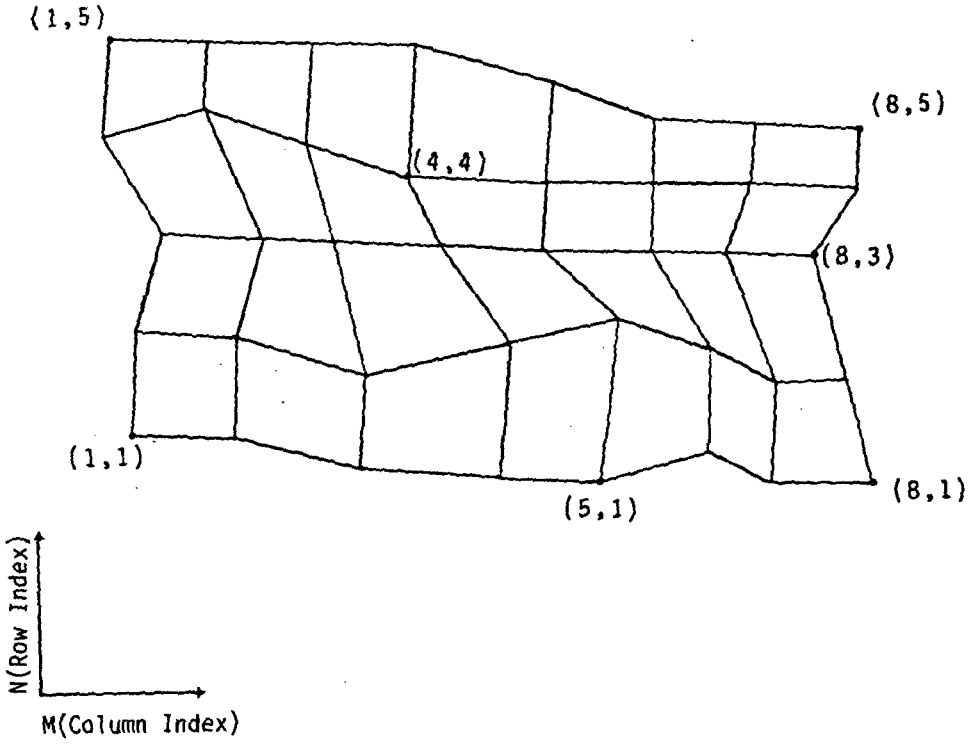



Figure 8.4 - Coarse Grid Lattice Indices (M,N)

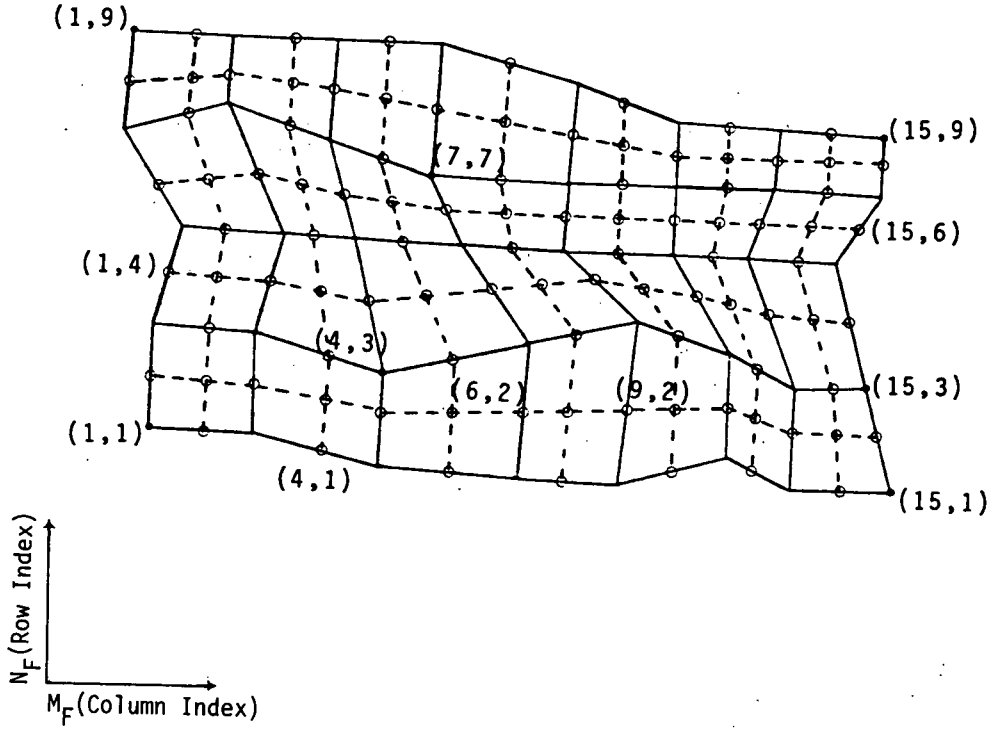
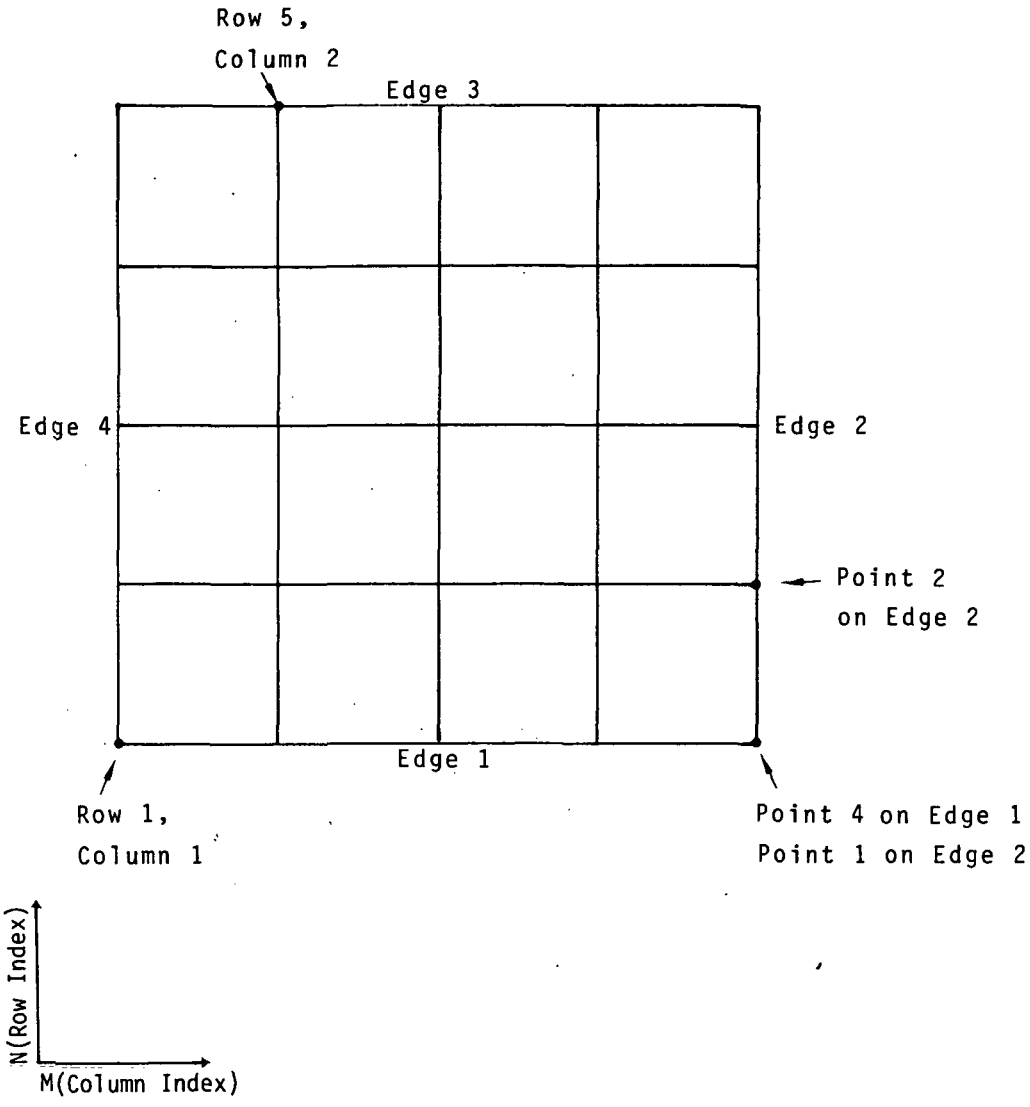
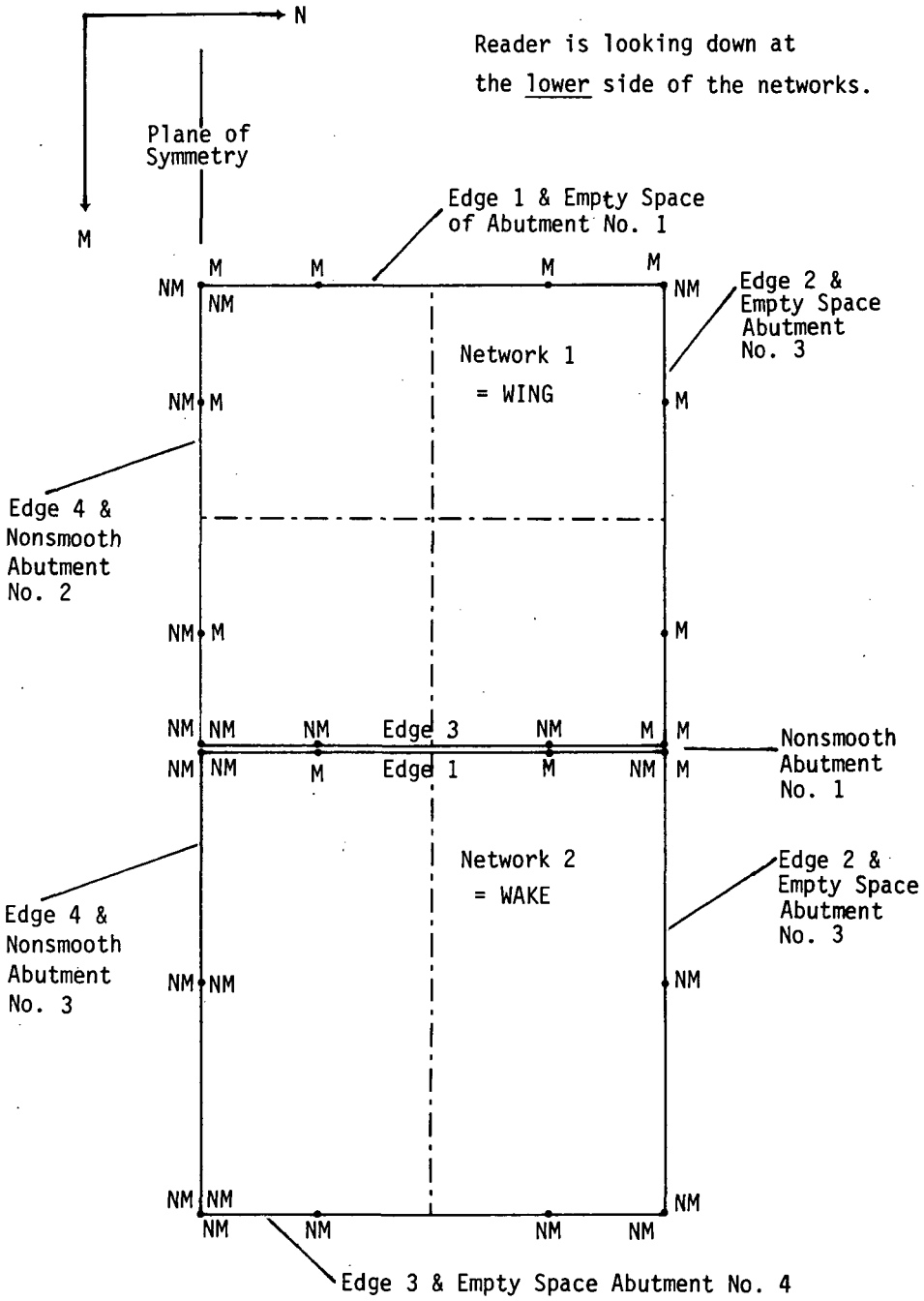



Figure 8.5 - Fine Grid Lattice Indices ($M_F N_F$)




a) Indexing of rows, columns, edges and edge points

Figure 8.6 - Abutment Indexing Scheme in DQG




b) Example with matching and nonmatching identifications at edge points

Figure 8.6 - Concluded

```
**************************************************
*                                                *
*   PROGRAM PDP      VERSION 1.0        NOW RUNNING.  *
*   THE PROGRAM IS PART OF THE PAN AIR SYSTEM     *
*   DATE OF RUN IS  05/16/80                      *
*   TIME OF RUN IS  10.04.45                      *
*                                                *
**************************************************

    DATA HASES TO BE USED

    DEFAULT    ACTUAL
    NAME       NAME       LOCATION        GENERATED BY
    -------    -------    ------ ------   ------ ------ --------
    DIP        DIPIC1     FAEBRP3 PANAIR
          MD   DIPMD      FAEBRP3 PANAIR
                                          DIP    1.0     05/16/80
                                          RID =   PAN AIR INSTALLATION CASE 1 FOR SAMPLE OUTPUT /
                                          PID =     = SIMPLE DELTA WING WITH THICKNESS
                                          UID =     USER IDENTIFICATION
    MDG        MDGIC1     FAEBRP3 PANAIR
          MD   MDGMD      FAEBRP3 PANAIR
                                          MDG    1.0     05/16/80
                                          RID =   PAN AIR INSTALLATION CASE 1 FOR SAMPLE OUTPUT /
                                          PID =     = SIMPLE DELTA WING WITH THICKNESS
                                          UID =     USER IDENTIFICATION
    PDPT       PDPT       FAEBRP3 PANAIR
          MD   PDPTMD     FAEBRP3 PANAIR
```

Figure 8.7 - Sample PDP output

```
ESTIMATE OF RESOURCE REQUIREMENTS      PAGE    1

DISK STORAGE REQUIREMENTS (CDC WORDS) FOR CASE NUMBER   1

      DATA BASE PDPT

      DATASET   CP-VEL                    .985E+03
      DATASET   GP-VEL                   0.

      TOTAL                               .985E+03


      DATA BASE PDP

      DATASET   SURF-OPTIONS              .580E+02
      DATASET   FLOW-QUANT                .229E+04

      TOTAL                               .235E+04


DISK STORAGE REQUIREMENTS (CDC WORDS) FOR CASE NUMBER   2

      DATA BASE PDPT

      DATASET   CP-VEL                    .205E+04
      DATASET   GP-VEL                   0.

      TOTAL                               .205E+04


      DATA BASE PDP

      DATASET   SURF-OPTIONS              .620E+02
      DATASET   FLOW-QUANT                .491E+04

      TOTAL                               .498E+04


TOTAL DISK STORAGE REQUIREMENTS FOR THIS RUN

      DATASET   GLOBAL                    .390E+02
      DATASET   NETWK-SPEC                .600E+01

      TOTAL SIZE OF DATABASE PDP          .737E+04

      TOTAL SIZE OF DATABASE PDPT         .205E+04

      TOTAL                               .942E+04
```

Figure 8.7 - Continued

```
    PDP         PDPIC1     FAEBRP3 PANAIR
          MD    PDPMD      FAEBRP3 PANAIR

*** AFTER OVLY (1,0)

*** AFTER OVLY (2,0)
```

Figure 8.7 - Continued

RID PAN AIR INSTALLATION CASE 1 FOR SAMPLE OUTPUT /

PID = SIMPLE DELTA WING WITH THICKNESS

UID USER IDENTIFICATION

---------- GLOBAL DATA FOR THIS RUN ----------

| | |
|---|---|
| NUMBER OF NETWORKS IN THE CONFIGURATION | 1 |
| NUMBER OF SOLUTIONS | 3 |
| NUMBER OF PLANES OF SYMMETRY | 2 |
| | PLANE 1 WITH SYMMETRIC FLOW |
| | PLANE 2 WITH ASYMMETRIC FLOW |
| FREESTREAM MACH NUMBER | 2.000 |
| CALPHA = 0.000 CBETA = 0.000 | |
| NUMBER OF USER OPTION CASES | 2 |

Figure 8.7 - Continued

NUMBER OF NETWORKS SELECTED 1

NUMBER OF SOLUTIONS SELECTED 1

| SOLUTION | ALPHA | BETA | UNIF | SOLUTION ID |
|---|---|---|---|---|
| 2 | 0.000 | 0.000 | 1.0 | SOLN-2 |

POINT TYPES SELECTED
PANEL CENTER CONTROL POINTS
NETWORK EDGE CONTROL POINTS
ADDITIONAL CONTROL POINTS

SURFACES SELECTED UPPER LOWER

VELOCITY COMPUTATION OPTION(S) B.C.

VELOCITY CORRECTION OPTION(S), NONE SA1 SA2
3 0 0

PRESSURE COMPUTATION OPTION(S) UNIFVL

********** FLOW QUANTITIES SELECTED **********

| ROW | COL | X-CORD | Y-CORD | Z-CORD | PWX | PWY | PWZ | WX | WY | WZ | WMAG |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 |

| WN | PVX | PVY | PVZ | VX | VY | VZ | VMAG | PHI | PHIT | MLISEN | MLLINE |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 |

| MLSECO | MLREDU | MLSLEN | CPISEN | CPLINE | CPSECO | CPREDU | CPSLEN | GMUX | GMUY | GMUZ | PSI |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 |

| SINGS | SINGD | SPDMAX | SPDCRT | CPVAC |
|---|---|---|---|---|
| 3 | 3 | 3 | 3 | 3 |

1 = PRINT ONLY, 2 = DATA BASE STORAGE ONLY, 3 = BOTH, 0 = NONE

Figure 8.7 - Continued

SOLUTION NO : 2,ID : SOLN-2 NETWORK NO : 1,ID : UPPER-WING ,IMAGE : INPUT ,ORIENTATION : RETAIN

ALPHA = 0.00 BETA = 0.00 MACH = 2.000 CALPHA = 0.00 CBETA = 0.00

PRESSURE COMPUTATION UNIFVL VELOCITY COMPUTATION B.C. VELOCITY CORRECTION NONE

| ROW | COL | X-CORD | Y-CORD | Z-CORD | PWX<br>PVX<br>PHIT<br>CPSECO<br>SINGD | PWY<br>PVY<br>MLISEN<br>CPREDU<br>SPDMAX | PWZ<br>PVZ<br>MLLINE<br>CPSLEN<br>SPDCRT | WX<br>VX<br>MLSECO<br>GMUX<br>CPVAC | WY<br>VY<br>MLREDU<br>GMUY | WZ<br>VZ<br>MLSLEN<br>GMUZ | WMAG<br>VMAG<br>CPISEN<br>PSI | WN<br>PHI<br>CPLINE<br>SINGS | SURFC |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 2 | 2 | .43750 | .24975 | .00939 | 0.00000 | 0.00000 | 0.00000 | 1.00000 | 0.00000 | 0.00000 | 1.00000 | .04988 | UPPER |
| | | | | | 0.00000 | 0.00000 | 0.00000 | 1.00000 | 0.00000 | 0.00000 | 1.00000 | 0.00000 | |
| | | | | | .43750 | 2.00000 | 2.00000 | 2.00000 | 2.00000 | 2.00000 | 0.00000 | 0.00000 | |
| | | | | | 0.00000 | 0.00000 | 0.00000 | .03337 | -.02412 | -.00380 | 0.00000 | .04983 | |
| | | | | | .01016 | 1.50000 | .61237 | -.35714 | | | | | |
| | | | | | .10763 | .02663 | .05400 | 1.10763 | .02663 | .05400 | 1.10927 | .00005 | LOWER |
| | | | | | -.03588 | .02663 | .05400 | .96412 | .02663 | .05400 | .96600 | -.01016 | |
| | | | | | .42734 | 1.88233 | 1.90975 | 1.88233 | 1.88233 | 1.88011 | .07143 | .07176 | |
| | | | | | .07199 | .06684 | .06813 | .03337 | -.02412 | -.00380 | 0.00000 | .04983 | |
| | | | | | .01016 | 1.50000 | .61237 | -.35714 | | | | | |
| 4 | 2 | .81263 | .24975 | .00937 | 0.00000 | 0.00000 | 0.00000 | 1.00000 | 0.00000 | 0.00000 | 1.00000 | -.04994 | UPPER |
| | | | | | 0.00000 | 0.00000 | 0.00000 | 1.00000 | 0.00000 | 0.00000 | 1.00000 | 0.00000 | |
| | | | | | .81263 | 2.00000 | 2.00000 | 2.00000 | 2.00000 | 2.00000 | 0.00000 | 0.00000 | |
| | | | | | 0.00000 | 0.00000 | 0.00000 | -.03505 | .01359 | -.00586 | 0.00000 | -.04999 | |
| | | | | | .00706 | 1.50000 | .61237 | -.35714 | | | | | |
| | | | | | -.10957 | -.01359 | -.04457 | .89043 | -.01359 | -.04457 | .89164 | .00005 | LOWER |
| | | | | | .03652 | -.01359 | -.04457 | 1.03652 | -.01359 | -.04457 | 1.03757 | -.00706 | |
| | | | | | .80557 | 2.14176 | 2.09844 | 2.14176 | 2.14176 | 2.13922 | -.07087 | -.07305 | |
| | | | | | -.07192 | -.07656 | -.07522 | -.03905 | .01359 | -.00586 | 0.00000 | -.04999 | |
| | | | | | .00706 | 1.50000 | .61237 | -.35714 | | | | | |
| 2 | 4 | .81238 | .74975 | .00313 | 0.00000 | 0.00000 | 0.00000 | 1.00000 | 0.00000 | 0.00000 | 1.00000 | .04988 | UPPER |
| | | | | | 0.00000 | 0.00000 | 0.00000 | 1.00000 | 0.00000 | 0.00000 | 1.00000 | 0.00000 | |
| | | | | | .81238 | 2.00000 | 2.00000 | 2.00000 | 2.00000 | 2.00000 | 0.00000 | 0.00000 | |
| | | | | | 0.00000 | 0.00000 | 0.00000 | .04483 | -.05039 | -.00420 | 0.00000 | .04988 | |
| | | | | | .00345 | 1.50000 | .61237 | -.35714 | | | | | |
| | | | | | .14202 | .05290 | .05446 | 1.14202 | .05290 | .05446 | 1.14454 | -.00000 | LOWER |
| | | | | | -.04734 | .05290 | .05446 | .95266 | .05290 | .05446 | .95568 | -.00345 | |
| | | | | | .80842 | 1.84835 | 1.88211 | 1.84835 | 1.84835 | 1.84454 | .09445 | .09468 | |
| | | | | | .09564 | .08667 | .08691 | .04483 | -.05039 | -.00420 | 0.00000 | .04988 | |
| | | | | | .00345 | 1.50000 | .61237 | -.35714 | | | | | |
| 4 | 4 | .93750 | .74975 | .00313 | 0.00000 | 0.00000 | 0.00000 | 1.00000 | 0.00000 | 0.00000 | 1.00000 | -.04994 | UPPER |
| | | | | | 0.00000 | 0.00000 | 0.00000 | 1.00000 | 0.00000 | 0.00000 | 1.00000 | 0.00000 | |
| | | | | | .93750 | 2.00000 | 2.00000 | 2.00000 | 2.00000 | 2.00000 | 0.00000 | 0.00000 | |
| | | | | | 0.00000 | 0.00000 | 0.00000 | .00321 | -.01638 | .00048 | 0.00000 | -.04989 | |
| | | | | | .00654 | 1.50000 | .61237 | -.35714 | | | | | |

Figure 8.7 - Continued

SURFACE FLOW PROPERTIES AT PANEL CENTER CONTROL POINTS CASE NUMBER 1 ID ZERO-ALPHA PAGE 4

| ROW | COL | X-CORD | Y-CORD | Z-CORD | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | PWX | PWY | PWZ | WX | WY | WZ | WMAG | WN | SURFC |
| | | | | | PVX | PVY | PVZ | VX | VY | VZ | VMAG | PHI | |
| | | | | | PHIT | MLISEN | MLLINE | MLSECO | MLREDU | MLSLEN | CPISEN | CPLINE | |
| | | | | | CPSECO | CPREDU | CPSLEN | GMUX | GMUY | GMUZ | PSI | SINGS | |
| | | | | | SINGD | SPDMAX | SPDCRT | CPVAC | | | | | |
| 4 | 4 | .93750 | .74975 | .00313 | .01717 | .01638 | -.05081 | 1.01717 | .01638 | -.05081 | 1.01857 | -.00005 | LOWER |
| | | | | | -.00572 | .01638 | -.05081 | .99428 | .01638 | -.05081 | .99571 | -.00654 | |
| | | | | | .93096 | 1.98464 | 1.98520 | 1.98464 | 1.98464 | 1.98458 | .00863 | .01144 | |
| | | | | | .00869 | .00856 | .00859 | .00321 | -.01638 | .00048 | 0.00000 | -.04989 | |
| | | | | | .00654 | 1.50000 | .61237 | -.357.14 | | | | | |

Figure 8.7 - Continued

| ROW | COL | X-CORD | Y-CORD | Z-CORD | PWX<br>PVX<br>PHIT<br>CPSECO<br>SINGD | PWY<br>PVY<br>MLISEN<br>CPREDU<br>SPDMAX | PWZ<br>PVZ<br>MLLINE<br>CPSLEN<br>SPDCRT | WX<br>VX<br>MLSECO<br>GMUX<br>CPVAC | WY<br>VY<br>MLREDU<br>GMUY | WZ<br>VZ<br>MLSLEN<br>GMUZ | WMAG<br>VMAG<br>CPISEN<br>PSI | WN<br>PHI<br>CPLINE<br>SINGS | SURFC |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 2 | .25938 | .23750 | .00109 | 0.00000<br>0.00000<br>.25938<br>0.00000<br>.00152 | 0.00000<br>0.00000<br>2.00000<br>0.00000<br>1.50000 | 0.00000<br>0.00000<br>2.00000<br>0.00000<br>.61237 | 1.00000<br>1.00000<br>2.00000<br>.07031<br>-.35714 | 0.00000<br>0.00000<br>2.00000<br>-.06446 | 0.00000<br>0.00000<br>2.00000<br>-.00732 | 1.00000<br>1.00000<br>0.00000<br>0.00000 | .04988<br>0.00000<br>0.00000<br>.09471 | UPPER |
| | | | | | .22525<br>-.07508<br>.25786<br>.15173<br>.00152 | .06923<br>.06923<br>1.77680<br>.12918<br>1.50000 | .10274<br>.10274<br>1.81738<br>.13482<br>.61237 | 1.22525<br>.92492<br>1.77680<br>.07031<br>-.35714 | .06923<br>.06923<br>1.77680<br>-.06446 | .10274<br>.10274<br>1.76743<br>-.00732 | 1.23150<br>.93318<br>.14674<br>0.00000 | -.04483<br>-.00152<br>.15017<br>.09471 | LOWER |
| 1 | 4 | .74688 | .73750 | .00047 | 0.00000<br>0.00000<br>.74688<br>0.00000<br>.00065 | 0.00000<br>0.00000<br>2.00000<br>0.00000<br>1.50000 | 0.00000<br>0.00000<br>2.00000<br>0.00000<br>.61237 | 1.00000<br>1.00000<br>2.00000<br>.06273<br>-.35714 | 0.00000<br>0.00000<br>2.00000<br>-.06450 | 0.00000<br>0.00000<br>2.00000<br>-.00618 | 1.00000<br>1.00000<br>0.00000<br>0.00000 | .04988<br>0.00000<br>0.00000<br>.09498 | UPPER |
| | | | | | .20255<br>-.06752<br>.74623<br>.13352<br>.00065 | .06929<br>.06929<br>1.80000<br>.11529<br>1.50000 | .10188<br>.10188<br>1.83475<br>.11985<br>.61237 | 1.20255<br>.93248<br>1.80000<br>.06273<br>-.35714 | .06929<br>.06929<br>1.80000<br>-.06450 | .10188<br>.10188<br>1.79237<br>-.00618 | 1.20884<br>.94059<br>.12920<br>0.00000 | -.04511<br>-.00065<br>.13503<br>.09498 | LOWER |
| 5 | 2 | .98438 | .26250 | .00078 | 0.00000<br>0.00000<br>.98438<br>0.00000<br>-.00093 | 0.00000<br>0.00000<br>2.00000<br>0.00000<br>1.50000 | 0.00000<br>0.00000<br>2.00000<br>0.00000<br>.61237 | 1.00000<br>1.00000<br>2.00000<br>-.05709<br>-.35714 | 0.00000<br>0.00000<br>2.00000<br>.01912 | 0.00000<br>0.00000<br>2.00000<br>-.00856 | 1.00000<br>1.00000<br>0.00000<br>0.00000 | -.04994<br>0.00000<br>0.00000<br>-.09492 | UPPER |
| | | | | | -.15690<br>.05230<br>.98530<br>-.10436<br>-.00093 | -.01912<br>-.01912<br>2.21688<br>-.11530<br>1.50000 | -.08719<br>-.08719<br>2.14327<br>-.11257<br>.61237 | .84310<br>1.05230<br>2.21688<br>-.05709<br>-.35714 | -.01912<br>-.01912<br>2.21688<br>.01912 | -.08719<br>-.08719<br>2.21149<br>-.00856 | .84781<br>1.05608<br>-.10261<br>0.00000 | .04498<br>.00093<br>-.10460<br>-.09492 | LOWER |
| 5 | 4 | .99688 | .76250 | .00015 | 0.00000<br>0.00000<br>.99688<br>0.00000<br>.00598 | 0.00000<br>0.00000<br>2.00000<br>0.00000<br>1.50000 | 0.00000<br>0.00000<br>2.00000<br>0.00000<br>.61237 | 1.00000<br>1.00000<br>2.00000<br>-.01673<br>-.35714 | 0.00000<br>0.00000<br>2.00000<br>-.00881 | 0.00000<br>0.00000<br>2.00000<br>-.00251 | 1.00000<br>1.00000<br>0.00000<br>0.00000 | -.04994<br>0.00000<br>0.00000<br>.00258 | UPPER |
| | | | | | -.05058<br>.01686<br>.99090<br>-.03297<br>.00598 | .00881<br>.00881<br>2.06215<br>-.03411<br>1.50000 | .00511<br>.00511<br>2.04456<br>-.03383<br>.61237 | .94942<br>1.01686<br>2.06215<br>-.01673<br>-.35714 | .00881<br>.00881<br>2.06215<br>-.00881 | .00511<br>.00511<br>2.06163<br>-.00251 | .94947<br>1.01691<br>-.03296<br>0.00000 | -.05252<br>-.00598<br>-.03372<br>.00258 | LOWER |

Figure 8.7 - Continued

SURFACE FLOW PROPERTIES AT NETWORK EDGE CONTROL POINTS CASE NUMBER 1 ID ZERO-ALPHA PAGE 6

| ROW | COL | X-CORD | Y-CORD | Z-CORD | PWX<br>PVX<br>PHIT<br>CPSECO<br>SINGD | PWY<br>PVY<br>MLISEN<br>CPREDU<br>SPDMAX | PWZ<br>PVZ<br>MLLINE<br>CPSLEN<br>SPDCRT | WX<br>VX<br>MLSECO<br>GMUX<br>CPVAC | WY<br>VY<br>MLREDU<br>GMUY | WZ<br>VZ<br>MLSLEN<br>GMUZ | WMAG<br>VMAG<br>CPISEN<br>PSI | WN<br>PHI<br>CPLINE<br>SINGS | SURFC |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 2 | 1 | .27813 | .02500 | .01266 | 0.00000<br>0.00000<br>.27813<br>0.00000<br>.00856 | 0.00000<br>0.00000<br>2.00000<br>0.00000<br>1.50000 | 0.00000<br>0.00000<br>2.00000<br>0.00000<br>.61237 | 1.00000<br>1.00000<br>2.00000<br>.02526<br>-.35714 | 0.00000<br>0.00000<br>2.00000<br>-.00333 | 0.00000<br>0.00000<br>2.00000<br>-.00362 | 1.00000<br>1.00000<br>2.00000<br>0.00000 | .04988<br>0.00000<br>0.00000<br>.04725 | UPPER |
| | | | | | .08291<br>-.02764<br>.26956<br>.05491<br>.00856 | .00571<br>.00571<br>1.90827<br>.05186<br>1.50000 | .05123<br>.05123<br>1.92996<br>.05262<br>.61237 | 1.08291<br>.97236<br>1.90827<br>.02526<br>-.35714 | .00571<br>.00571<br>1.90827<br>-.00333 | .05123<br>.05123<br>1.90695<br>-.00362 | 1.08414<br>.97373<br>.05460<br>0.00000 | .00263<br>-.00856<br>.05528<br>.04725 | LOWER |
| 4 | 1 | .76563 | .02500 | .01172 | 0.00000<br>0.00000<br>.76563<br>0.00000<br>.00572 | 0.00000<br>0.00000<br>2.00000<br>0.00000<br>1.50000 | 0.00000<br>0.00000<br>2.00000<br>0.00000<br>.61237 | 1.00000<br>1.00000<br>2.00000<br>-.03248<br>-.35714 | 0.00000<br>0.00000<br>2.00000<br>.01318 | 0.00000<br>0.00000<br>2.00000<br>-.00487 | 1.00000<br>1.00000<br>0.00000<br>0.00000 | -.04994<br>0.00000<br>0.00000<br>-.05246 | UPPER |
| | | | | | -.08950<br>.02983<br>.75991<br>-.05948<br>.00572 | -.01318<br>-.01318<br>2.11613<br>-.06304<br>1.50000 | -.04805<br>-.04805<br>2.07986<br>-.06215<br>.61237 | .91050<br>1.02983<br>2.11613<br>-.03248<br>-.35714 | -.01318<br>-.01318<br>2.11613<br>.01318 | -.04805<br>-.04805<br>2.11445<br>-.00487 | .91186<br>1.03104<br>-.05917<br>0.00000 | .00252<br>-.00572<br>-.05967<br>-.05246 | LOWER |

Figure 8.7 - Continued

| ROW | COL | X-CORD | Y-CORD | Z-CORD | PWX<br>PVX<br>PHIT<br>CPSECO<br>SINGD | PWY<br>PVY<br>MLISEN<br>CPREDU<br>SPDMAX | PWZ<br>PVZ<br>MLLINE<br>CPSLEN<br>SPDCRT | WX<br>VX<br>MLSECO<br>GMUX<br>CPVAC | WY<br>VY<br>MLREDU<br>GMUY | WZ<br>VZ<br>MLSLEN<br>GMUZ | WMAG<br>VMAG<br>CPISEN<br>PSI | WN<br>PHI<br>CPLINE<br>SINGS | SURFC |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 1 | .02500 | .01250 | .00063 | 0.00000 | 0.00000 | 0.00000 | 1.00000 | 0.00000 | 0.00000 | 1.00000 | .04988 | UPPER |
| | | | | | 0.00000 | 0.00000 | 0.00000 | 1.00000 | 0.00000 | 0.00000 | 1.00000 | 0.00000 | |
| | | | | | .02500 | 2.00000 | 2.00000 | 2.00000 | 2.00000 | 2.00000 | 0.00000 | 0.00000 | |
| | | | | | 0.00000 | 0.00000 | 0.00000 | .04235 | -.04263 | -.00422 | 0.00000 | .09704 | |
| | | | | | .00081 | 1.50000 | .61237 | -.35714 | | | | | |
| | | | | | .14173 | .04752 | .10199 | 1.14173 | .04752 | .10199 | 1.14726 | -.04717 | LOWER |
| | | | | | -.04724 | .04752 | .10199 | .95276 | .04752 | .10199 | .95938 | -.00081 | |
| | | | | | .02419 | 1.86044 | 1.88234 | 1.86044 | 1.86044 | 1.85662 | .08613 | .09449 | |
| | | | | | .08852 | .07959 | .08183 | .04235 | -.04263 | -.00422 | 0.00000 | .09704 | |
| | | | | | .00081 | 1.50000 | .61237 | -.35714 | | | | | |
| 1 | 5 | .99271 | .99167 | .00005 | 0.00000 | 0.00000 | 0.00000 | 1.00000 | 0.00000 | 0.00000 | 1.00000 | .04988 | UPPER |
| | | | | | 0.00000 | 0.00000 | 0.00000 | 1.00000 | 0.00000 | 0.00000 | 1.00000 | 0.00000 | |
| | | | | | .99271 | 2.00000 | 2.00000 | 2.00000 | 2.00000 | 2.00000 | 0.00000 | 0.00000 | |
| | | | | | 0.00000 | 0.00000 | 0.00000 | .04225 | -.04258 | -.00421 | 0.00000 | .09928 | |
| | | | | | .00007 | 1.50000 | .61237 | -.35714 | | | | | |
| | | | | | .14174 | .04758 | .10423 | 1.14174 | .04758 | .10423 | 1.14748 | -.04940 | LOWER |
| | | | | | -.04725 | .04758 | .10423 | .95275 | .04758 | .10423 | .95962 | -.00007 | |
| | | | | | .99264 | 1.86122 | 1.88233 | 1.86122 | 1.86122 | 1.85740 | .08560 | .09450 | |
| | | | | | .08807 | .07914 | .08137 | .04225 | -.04258 | -.00421 | 0.00000 | .09928 | |
| | | | | | .00007 | 1.50000 | .61237 | -.35714 | | | | | |
| 5 | 1 | .98750 | .01250 | .00063 | 0.00000 | 0.00000 | 0.00000 | 1.00000 | 0.00000 | 0.00000 | 1.00000 | -.04994 | UPPER |
| | | | | | 0.00000 | 0.00000 | 0.00000 | 1.00000 | 0.00000 | 0.00000 | 1.00000 | 0.00000 | |
| | | | | | .98750 | 2.00000 | 2.00000 | 2.00000 | 2.00000 | 2.00000 | 0.00000 | 0.00000 | |
| | | | | | 0.00000 | 0.00000 | 0.00000 | -.05186 | .00271 | -.00778 | 0.00000 | -.09737 | |
| | | | | | -.00346 | 1.50000 | .61237 | -.35714 | | | | | |
| | | | | | -.14085 | -.00271 | -.09045 | .85915 | -.00271 | -.09045 | .86390 | .04744 | LOWER |
| | | | | | .04695 | -.00271 | -.09045 | 1.04695 | -.00271 | -.09045 | 1.05085 | .00346 | |
| | | | | | .99096 | 2.19528 | 2.12789 | 2.19528 | 2.19528 | 2.19098 | -.09386 | -.09390 | |
| | | | | | -.09548 | -.10429 | -.10209 | -.05186 | .00271 | -.00778 | 0.00000 | -.09737 | |
| | | | | | -.00346 | 1.50000 | .61237 | -.35714 | | | | | |

Figure 8.7 - Continued

SOLUTION NO : 2,ID : SOLN-2 NETWORK NO : 1,ID : UPPER-WING ,IMAGE : 3RD ,ORIENTATION : RETAIN

ALPHA = 0.00 BETA = 0.00 MACH = 2.000 CALPHA = 0.00 CBETA = 0.00

PRESSURE COMPUTATION UNIFVL VELOCITY COMPUTATION B.C. VELOCITY CORRECTION NONE

| ROW | COL | X-CORD | Y-CORD | Z-CORD | PWX<br>PVX<br>PHIT<br>CPSECO<br>SINSD | PWY<br>PVY<br>MLISEN<br>CPREDU<br>SPDMAX | PWZ<br>PVZ<br>MLLINE<br>CPSLEN<br>SPDCRT | WX<br>VX<br>MLSECO<br>GMUX<br>CPVAC | WY<br>VY<br>MLREDU<br>GMUY | WZ<br>VZ<br>MLSLEN<br>GMUZ | WMAG<br>VMAG<br>CPISEN<br>PSI | WN<br>PHI<br>CPLINE<br>SINGS | SURFC |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 2 | 2 | .43750 | .24975 | -.00939 | 0.00000 | 0.00000 | 0.00000 | 1.00000 | 0.00000 | 0.00000 | 1.00000 | .04988 | UPPER |
| | | | | | *0.00000* | *0.00000* | *0.00000* | *1.00000* | *0.00000* | *0.00000* | *1.00000* | *0.00000* | |
| | | | | | .43750 | 2.00000 | 2.00000 | 2.00000 | 2.00000 | 2.00000 | 0.00000 | 0.00000 | |
| | | | | | 0.00000 | 0.00000 | 0.00000 | .03337 | -.02412 | .00380 | 0.00000 | .04983 | |
| | | | | | .01016 | 1.50000 | .61237 | -.35714 | | | | | |
| | | | | | .10763 | .02663 | -.05400 | 1.10763 | .02663 | -.05400 | 1.10927 | .00005 | LOWER |
| | | | | | -.03588 | .02663 | -.05400 | .96412 | .02663 | -.05400 | .96600 | -.01016 | |
| | | | | | .42734 | 1.88233 | 1.90975 | 1.88233 | 1.88233 | 1.88011 | .07143 | .07176 | |
| | | | | | .07199 | .06684 | .06813 | .03337 | -.02412 | .00380 | 0.00000 | .04983 | |
| | | | | | .01016 | 1.50000 | .61237 | -.35714 | | | | | |
| 4 | 2 | .81263 | .24975 | -.00937 | 0.00000 | 0.00000 | 0.00000 | 1.00000 | 0.00000 | 0.00000 | 1.00000 | -.04994 | UPPER |
| | | | | | 0.00000 | 0.00000 | 0.00000 | 1.00000 | 0.00000 | 0.00000 | 1.00000 | 0.00000 | |
| | | | | | .81263 | 2.00000 | 2.00000 | 2.00000 | 2.00000 | 2.00000 | 0.00000 | 0.00000 | |
| | | | | | 0.00000 | 0.00000 | 0.00000 | -.03905 | .01359 | .00586 | 0.00000 | -.04999 | |
| | | | | | .00706 | 1.50000 | .61237 | -.35714 | | | | | |
| | | | | | -.10757 | -.01359 | .04457 | .89043 | -.01359 | .04457 | .89164 | .00005 | LOWER |
| | | | | | .03652 | -.01359 | .04457 | 1.03652 | -.01359 | .04457 | 1.03757 | -.00706 | |
| | | | | | .80557 | 2.14176 | 2.09844 | 2.14176 | 2.14176 | 2.13922 | -.07087 | -.07305 | |
| | | | | | -.07122 | -.07656 | -.07522 | -.03905 | .01359 | .00586 | 0.00000 | -.04999 | |
| | | | | | .00706 | 1.50000 | .61237 | -.35714 | | | | | |
| 2 | 4 | .81238 | .74975 | -.00513 | 0.00000 | 0.00000 | 0.00000 | 1.00000 | 0.00000 | 0.00000 | 1.00000 | .04988 | UPPER |
| | | | | | 0.00000 | 0.00000 | 0.00000 | 1.00000 | 0.00000 | 0.00000 | 1.00000 | 0.00000 | |
| | | | | | .81238 | 2.00000 | 2.00000 | 2.00000 | 2.00000 | 2.00000 | 0.00000 | 0.00000 | |
| | | | | | 0.00000 | 0.00000 | 0.00000 | .04483 | -.05039 | .00420 | 0.00000 | .04988 | |
| | | | | | .00345 | 1.50000 | .61237 | -.35714 | | | | | |
| | | | | | .14202 | .05290 | -.05446 | 1.14202 | .05290 | -.05446 | 1.14454 | -.00000 | LOWER |
| | | | | | -.04734 | .05290 | -.05446 | .95266 | .05290 | -.05446 | .95568 | -.00345 | |
| | | | | | .80892 | 1.84835 | 1.88211 | 1.84835 | 1.84835 | 1.84454 | .09445 | .09468 | |
| | | | | | .09584 | .08667 | .08891 | .04483 | -.05039 | .00420 | 0.00000 | .04988 | |
| | | | | | .00345 | 1.50000 | .61237 | -.35714 | | | | | |
| 4 | 4 | .93750 | .74975 | -.00513 | 0.00000 | 0.00000 | 0.00000 | 1.00000 | 0.00000 | 0.00000 | 1.00000 | -.04994 | UPPER |
| | | | | | 0.00000 | 0.00000 | 0.00000 | 1.00000 | 0.00000 | 0.00000 | 1.00000 | 0.00000 | |
| | | | | | .93750 | 2.00000 | 2.00000 | 2.00000 | 2.00000 | 2.00000 | 0.00000 | 0.00000 | |
| | | | | | 0.00000 | 0.00000 | 0.00000 | .00321 | -.01638 | -.00048 | 0.00000 | -.04989 | |
| | | | | | .00654 | 1.50000 | .61237 | -.35714 | | | | | |

Figure 8.7 - Continued

SURFACE FLOW PROPERTIES AT PANEL CENTER CONTROL POINTS CASE NUMBER 1 ID ZERO-ALPHA PAGE 9

| ROW | COL | X-CORD | Y-CORD | Z-CORD | PWX | PWY | PWZ | WX | WY | WZ | WMAG | WN | SURFC |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | PVX | PVY | PVZ | VX | VY | VZ | VMAG | PHI | |
| | | | | | PHIT | MLISEN | MLLINE | MLSECO | MLREDU | MLSLEN | CPISEN | CPLINE | |
| | | | | | CPSECO | CPREDU | CPSLEN | GMUX | GMUY | GMUZ | PSI | SINGS | |
| | | | | | SINGD | SPDMAX | SPDCRT | CPVAC | | | | | |
| 4 | 4 | .93750 | .74975 | -.00313 | .01717 | .01638 | .05081 | 1.01717 | .01638 | .05081 | 1.01857 | -.00005 | LOWER |
| | | | | | -.00572 | .01638 | .05081 | .99428 | .01638 | .05081 | .99571 | -.00654 | |
| | | | | | .93096 | 1.98464 | 1.98520 | 1.98464 | 1.98464 | 1.98458 | .00863 | .01144 | |
| | | | | | .00869 | .00856 | .00859 | .00321 | -.01638 | -.00048 | 0.00000 | -.04989 | |
| | | | | | .00654 | 1.50000 | .61237 | -.35714 | | | | | |

Figure 8.7 - Continued

| ROW | COL | X-CORD | Y-CORD | Z-CORD | PWX | PWY | PWZ | WX | WY | WZ | WMAG | WN | SURFC |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | PVX | PVY | PVZ | VX | VY | VZ | VMAG | PHI | |
| | | | | | PHIT | MLISEN | MLLINE | MLSECO | MLREDU | MLSLEN | CPISEN | CPLINE | |
| | | | | | CPSECO | CPREDU | CPSLEN | GMUX | GMUY | GMUZ | PSI | SINGS | |
| | | | | | SINGO | SPDMAX | SPDCRT | CPVAC | | | | | |
| 1 | 2 | .25938 | .23750 | -.00109 | 0.00000 | 0.00000 | 0.00000 | 1.00000 | 0.00000 | 0.00000 | 1.00000 | .04988 | UPPER |
| | | | | | 0.00000 | 0.00000 | 0.00000 | 1.00000 | 0.00000 | 0.00000 | 1.00000 | 0.00000 | |
| | | | | | .25938 | 2.00000 | 2.00000 | 2.00000 | 2.00000 | 2.00000 | 0.00000 | 0.00000 | |
| | | | | | 0.00000 | 0.00000 | 0.00000 | .07031 | -.06446 | .00732 | 0.00000 | .09471 | |
| | | | | | .00152 | 1.50000 | .61237 | -.35714 | | | | | |
| | | | | | .22525 | .06923 | -.10274 | 1.22525 | .06923 | -.10274 | 1.23150 | -.04483 | LOWER |
| | | | | | -.07508 | .06923 | -.10274 | .92492 | .06923 | -.10274 | .93318 | -.00152 | |
| | | | | | .25786 | 1.77680 | 1.81738 | 1.77680 | 1.77680 | 1.76743 | .14674 | .15017 | |
| | | | | | .15173 | .12918 | .13482 | .07031 | -.06446 | .00732 | 0.00000 | .09471 | |
| | | | | | .00152 | 1.50000 | .61237 | -.35714 | | | | | |
| 1 | 4 | .74688 | .73750 | -.00047 | 0.00000 | 0.00000 | 0.00000 | 1.00000 | 0.00000 | 0.00000 | 1.00000 | .04988 | UPPER |
| | | | | | 0.00000 | 0.00000 | 0.00000 | 1.00000 | 0.00000 | 0.00000 | 1.00000 | 0.00000 | |
| | | | | | .74688 | 2.00000 | 2.00000 | 2.00000 | 2.00000 | 2.00000 | 0.00000 | 0.00000 | |
| | | | | | 0.00000 | 0.00000 | 0.00000 | .06273 | -.06450 | .00618 | 0.00000 | .09498 | |
| | | | | | .00065 | 1.50000 | .61237 | -.35714 | | | | | |
| | | | | | .20255 | .06929 | -.10188 | 1.20255 | .06929 | -.10188 | 1.20884 | -.04511 | LOWER |
| | | | | | -.06752 | .06929 | -.10188 | .93248 | .06929 | -.10188 | .94059 | -.00065 | |
| | | | | | .74623 | 1.80000 | 1.83475 | 1.80000 | 1.80000 | 1.79237 | .12920 | .13503 | |
| | | | | | .13352 | .11529 | .11985 | .06273 | -.06450 | .00618 | 0.00000 | .09498 | |
| | | | | | .00065 | 1.50000 | .61237 | -.35714 | | | | | |
| 5 | 2 | .98438 | .26250 | -.00078 | 0.00000 | 0.00000 | 0.00000 | 1.00000 | 0.00000 | 0.00000 | 1.00000 | -.04994 | UPPER |
| | | | | | 0.00000 | 0.00000 | 0.00000 | 1.00000 | 0.00000 | 0.00000 | 1.00000 | 0.00000 | |
| | | | | | .98438 | 2.00000 | 2.00000 | 2.00000 | 2.00000 | 2.00000 | 0.00000 | 0.00000 | |
| | | | | | 0.00000 | 0.00000 | 0.00000 | -.05709 | .01912 | .00856 | 0.00000 | -.09492 | |
| | | | | | -.00093 | 1.50000 | .61237 | -.35714 | | | | | |
| | | | | | -.15690 | -.01912 | .08719 | .84310 | -.01912 | .08719 | .84781 | .04498 | LOWER |
| | | | | | .05230 | -.01912 | .08719 | 1.05230 | -.01912 | .08719 | 1.05608 | .00093 | |
| | | | | | .98530 | 2.21688 | 2.14327 | 2.21688 | 2.21688 | 2.21149 | -.10261 | -.10460 | |
| | | | | | -.10436 | -.11530 | -.11257 | -.05709 | .01912 | .00856 | 0.00000 | -.09492 | |
| | | | | | -.00093 | 1.50000 | .61237 | -.35714 | | | | | |
| 5 | 4 | .99688 | .76250 | -.00016 | 0.00000 | 0.00000 | 0.00000 | 1.00000 | 0.00000 | 0.00000 | 1.00000 | -.04994 | UPPER |
| | | | | | 0.00000 | 0.00000 | 0.00000 | 1.00000 | 0.00000 | 0.00000 | 1.00000 | 0.00000 | |
| | | | | | .99688 | 2.00000 | 2.00000 | 2.00000 | 2.00000 | 2.00000 | 0.00000 | 0.00000 | |
| | | | | | 0.00000 | 0.00000 | 0.00000 | -.01673 | -.00881 | .00251 | 0.00000 | .00258 | |
| | | | | | .00598 | 1.50000 | .61237 | -.35714 | | | | | |
| | | | | | -.05098 | .00881 | -.00511 | .94942 | .00881 | -.00511 | .94947 | -.05252 | LOWER |
| | | | | | .01686 | .00881 | -.00511 | 1.01686 | .00881 | -.00511 | 1.01691 | -.00598 | |
| | | | | | .99090 | 2.06215 | 2.04456 | 2.06215 | 2.06215 | 2.06163 | -.03296 | -.03372 | |
| | | | | | -.03297 | -.03411 | -.03383 | -.01673 | -.00881 | .00251 | 0.00000 | .00258 | |
| | | | | | .00598 | 1.50000 | .61237 | -.35714 | | | | | |

Figure 8.7 - Continued

| ROW | COL | X-CORD | Y-CORD | Z-CORD | PWX<br>PVX<br>PHIT<br>CPSECO<br>SINGD | PWY<br>PVY<br>MLISEN<br>CPREDU<br>SPDMAX | PWZ<br>PVZ<br>MLLINE<br>CPSLEN<br>SPDCRT | WX<br>VX<br>MLSECO<br>GMUX<br>CPVAC | WY<br>VY<br>MLREDU<br>GMUY | WZ<br>VZ<br>MLSLEN<br>GMUZ | WMAG<br>VMAG<br>CPISEN<br>PSI | WN<br>PHI<br>CPLINE<br>SINGS | SURFC |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 2 | 1 | .27813 | .02500 | -.01266 | 0.00000 | 0.00000 | 0.00000 | 1.00000 | 0.00000 | 0.00000 | 1.00000 | .04988 | UPPER |
| | | | | | 0.00000 | 0.00000 | 0.00000 | 1.00000 | 0.00000 | 0.00000 | 1.00000 | 0.00000 | |
| | | | | | .27813 | 2.00000 | 2.00000 | 2.00000 | 2.00000 | 2.00000 | 0.00000 | 0.00000 | |
| | | | | | 0.00000 | 0.00000 | 0.00000 | .02526 | -.00333 | .00362 | 0.00000 | .04725 | |
| | | | | | .00856 | 1.50000 | .61237 | -.35714 | | | | | |
| | | | | | .08291 | .00571 | -.05123 | 1.08291 | .00571 | -.05123 | 1.08414 | .00263 | LOWER |
| | | | | | -.02764 | .00571 | -.05123 | .97236 | .00571 | -.05123 | .97373 | -.00856 | |
| | | | | | .26956 | 1.90827 | 1.92996 | 1.90827 | 1.90827 | 1.90695 | .05460 | .05528 | |
| | | | | | .05491 | .05186 | .05262 | .02526 | -.00333 | .00362 | 0.00000 | .04725 | |
| | | | | | .00856 | 1.50000 | .61237 | -.35714 | | | | | |
| 4 | 1 | .76563 | .02500 | -.01172 | 0.00000 | 0.00000 | 0.00000 | 1.00000 | 0.00000 | 0.00000 | 1.00000 | -.04994 | UPPER |
| | | | | | 0.00000 | 0.00000 | 0.00000 | 1.00000 | 0.00000 | 0.00000 | 1.00000 | 0.00000 | |
| | | | | | .76563 | 2.00000 | 2.00000 | 2.00000 | 2.00000 | 2.00000 | 0.00000 | 0.00000 | |
| | | | | | 0.00000 | 0.00000 | 0.00000 | -.03248 | .01318 | .00487 | 0.00000 | -.05246 | |
| | | | | | .00572 | 1.50000 | .61237 | -.35714 | | | | | |
| | | | | | -.08950 | -.01318 | .04805 | .91050 | -.01318 | .04805 | .91186 | .00252 | LOWER |
| | | | | | .02983 | -.01318 | .04805 | 1.02983 | -.01318 | .04805 | 1.03104 | -.00572 | |
| | | | | | .75991 | 2.11613 | 2.07986 | 2.11613 | 2.11613 | 2.11495 | -.05917 | -.05967 | |
| | | | | | -.05948 | -.06304 | -.06215 | -.03248 | .01318 | .00487 | 0.00000 | -.05246 | |
| | | | | | .00572 | 1.50000 | .61237 | -.35714 | | | | | |

Figure 8.7 - Continued

| ROW | COL | X-CORD | Y-CORD | Z-CORD | PWX / PVX / PHIT / CPSECO / SINGD | PWY / PVY / MLISEN / CPREDU / SPDMAX | PWZ / PVZ / MLLINE / CPSLEN / SPDCRT | WX / VX / MLSECO / GMUX / CPVAC | WY / VY / MLREDU / GMUY | WZ / VZ / MLSLEN / GMUZ | WMAG / VMAG / CPISEN / PSI | WN / PHI / CPLINE / SINGS | SURFC |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 1 | .02500 | .01250 | -.00063 | 0.00000 | 0.00000 | 0.00000 | 1.00000 | 0.00000 | 0.00000 | 1.00000 | .04988 | UPPER |
| | | | | | 0.00000 | 0.00000 | 0.00000 | 1.00000 | 0.00000 | 0.00000 | 1.00000 | 0.00000 | |
| | | | | | .02500 | 2.00000 | 2.00000 | 2.00000 | 2.00000 | 2.00000 | 0.00000 | 0.00000 | |
| | | | | | 0.00000 | 0.00000 | 0.00000 | .04235 | -.04263 | .00422 | 0.00000 | .09704 | |
| | | | | | .00081 | 1.50000 | .61237 | -.35714 | | | | | |
| | | | | | .14173 | .04752 | -.10199 | 1.14173 | .04752 | -.10199 | 1.14726 | -.04717 | LOWER |
| | | | | | -.04724 | .04752 | -.10199 | .95276 | .04752 | -.10199 | .95938 | -.00081 | |
| | | | | | .02419 | 1.86044 | 1.88234 | 1.86044 | 1.86044 | 1.85662 | .08613 | .09449 | |
| | | | | | .08852 | .07959 | .08183 | .04235 | -.04263 | .00422 | 0.00000 | .09704 | |
| | | | | | .00081 | 1.50000 | .61237 | -.35714 | | | | | |
| 1 | 5 | .99271 | .99167 | -.00005 | 0.00000 | 0.00000 | 0.00000 | 1.00000 | 0.00000 | 0.00000 | 1.00000 | .04988 | UPPER |
| | | | | | 0.00000 | 0.00000 | 0.00000 | 1.00000 | 0.00000 | 0.00000 | 1.00000 | 0.00000 | |
| | | | | | .99271 | 2.00000 | 2.00000 | 2.00000 | 2.00000 | 2.00000 | 0.00000 | 0.00000 | |
| | | | | | 0.00000 | 0.00000 | 0.00000 | .04225 | -.04258 | .00421 | 0.00000 | .09928 | |
| | | | | | .00007 | 1.50000 | .61237 | -.35714 | | | | | |
| | | | | | .14174 | .04758 | -.10423 | 1.14174 | .04758 | -.10423 | 1.14748 | -.04940 | LOWER |
| | | | | | -.04725 | .04758 | -.10423 | .95275 | .04758 | -.10423 | .95962 | -.00007 | |
| | | | | | .99264 | 1.86122 | 1.88233 | 1.86122 | 1.86122 | 1.85740 | .08560 | .09450 | |
| | | | | | .08807 | .07914 | .08137 | .04225 | -.04258 | .00421 | 0.00000 | .09928 | |
| | | | | | .00007 | 1.50000 | .61237 | -.35714 | | | | | |
| 5 | 1 | .98750 | .01250 | -.00063 | 0.00000 | 0.00000 | 0.00000 | 1.00000 | 0.00000 | 0.00000 | 1.00000 | -.04994 | UPPER |
| | | | | | 0.00000 | 0.00000 | 0.00000 | 1.00000 | 0.00000 | 0.00000 | 1.00000 | 0.00000 | |
| | | | | | .98750 | 2.00000 | 2.00000 | 2.00000 | 2.00000 | 2.00000 | 0.00000 | 0.00000 | |
| | | | | | 0.00000 | 0.00000 | 0.00000 | -.05186 | .00271 | .00778 | 0.00000 | -.09737 | |
| | | | | | -.00346 | 1.50000 | .61237 | -.35714 | | | | | |
| | | | | | -.14085 | -.00271 | .09045 | .85915 | -.00271 | .09045 | .86390 | .04744 | LOWER |
| | | | | | .04695 | -.00271 | .09045 | 1.04695 | -.00271 | .09045 | 1.05085 | .00346 | |
| | | | | | .99096 | 2.19528 | 2.12789 | 2.19528 | 2.19528 | 2.19098 | -.09386 | -.09390 | |
| | | | | | -.09548 | -.10429 | -.10209 | -.05186 | .00271 | .00778 | 0.00000 | -.09737 | |
| | | | | | -.00346 | 1.50000 | .61237 | -.35714 | | | | | |

*** AFTER OVLY (3,0)

*** AFTER OVLY (2,0)

Figure 8.7 - Continued

```
**************************************************
*                                                *
*   PROGRAM PDP      VERSION 1.0        IS FINISHED.  *
*   DATE OF RUN IS   05/16/80                     *
*   TIME OF RUN IS   10.07.40                     *
*                                                *
**************************************************

    CP SECONDS USED BY PDP        =       1.7780
```

Figure 8.7 - Concluded

```
**************************************************
*                                                *
*   PROGRAM CDP      VERSION 1.0        NOW RUNNING.  *
*   THE PROGRAM IS PART OF THE PAN AIR SYSTEM     *
*   DATE OF RUN IS  05/16/80                      *
*   TIME OF RUN IS  10.07.46                      *
*                                                *
**************************************************

    DATA BASES TO BE USED

    DEFAULT   ACTUAL
    NAME      NAME       LOCATION        GENERATED BY
    -------   ------     ------ ------   ------ ------ --------
    DIP       DIPIC1     FAEBRP3 PANAIR
          MD  DIPMD      FAEBRP3 PANAIR
                                         DIP    1.0     05/16/80
                                         RIC =   PAN AIR INSTALLATION CASE 1 FOR SAMPLE OUTPUT /
                                         PIC =     = SIMPLE DELTA WING WITH THICKNESS
                                         UIC =     USER IDENTIFICATION
    MDG       MDGIC1     FAEBRP3 PANAIR
          MD  MDGMD      FAEBRP3 PANAIR
                                         MDG    1.0     05/16/80
                                         RIC =   PAN AIR INSTALLATION CASE 1 FOR SAMPLE OUTPUT /
                                         PIC =     = SIMPLE DELTA WING WITH THICKNESS
                                         UIC =     USER IDENTIFICATION
    CDPT      CDPT       FAEBRP3 PANAIR
          MD  CDPTMD     FAEBRP3 PANAIR
    CDP       CDPIC1     FAEBRP3 PANAIR
          MD  CDPMD      FAEBRP3 PANAIR
```

Figure 8.8 - Sample CDP output

```
**********************************************************
**********************************************************
*****                                                *****
*****     CONFIGURATION DATA PROCESSOR               *****
**********************************************************
*****     CASE NUMBER   =   1  ALPHA-VARIATION-FM    *****
*****                                                *****
**********************************************************
**********************************************************
 OPTIONS SELECTED ARE
 --------------------

*****                                                *****
NUMBER OF NETWORKS            =   1
NUMBER OF SOLUTIONS           =   3
PRESSURE RULES                = ISENTROPIC LINEAR     2ND ORDER  RED. S.O.  SLEND. BDY
VELOCITY COMPUTATION METHODS =B.C.
VELOCITY CORRECTION           =NONE
SURFACE TYPE                  =LOWER
PRESSURE COMPUTATION OPTION   =UNIFORM ONSET FLOW


 PROGRAM OUTPUTS
 1=PRINT  2=DATABASE  3=BOTH  0=NONE

COLUMN SUM IN RCS    3
COLUMN SUM IN WAS    3
COLUMN SUM IN BAS    3
COLUMN SUM IN SAS    3
PANEL SUM IN RCS     3
PANEL SUM IN WAS     3
PANEL SUM IN BAS     3
PANEL SUM IN SAS     3
NETWORK SUM          3
CONFIGURATION SUM    3

ACCUM. OPTIONS
     VEL. COMPUTAT. BOUNDARY
     VEL. CORRECTN. NONE
     PRESSURE RULE  ISENTROPIC



SIZE OF COP TEMPORARY DATABASE   =    1296
```

Figure 8.8 - Continued

```
RID    PAN AIR INSTALLATION CASE 1 FOR SAMPLE OUTPUT /
PID     = SIMPLE DELTA WING WITH THICKNESS
UID     USER IDENTIFICATION
                    NUMBER OF NETWORKS IN THE CONFIGURATION   1
                    NUMBER OF SOLUTIONS                       3
                    NUMBER OF PLANES OF SYMMETRY              2
                          PLANE 1 WITH SYMMETRIC  FLOW
                          PLANE 2 WITH ASYMMETRIC FLOW
                    FREESTREAM MACH NUMBER  2.000
                          CALPHA =   0.000  CBETA =   0.000 (DEGREES)
```

Figure 8.8 - Continued

NUMBER OF NETWORKS SELECTED 1

SURFACE SELECTED LOWER

VELOCITY COMPUTATION OPTIONS B.C.

VELOCITY CORRECTION OPTIONS NONE

PRESSURE RULES SELECTED ISEN LINE SECO REDU SLEN

| AXIS | COORD. OF MOMENT REFERENCE | | | EULER ANGLES |
|---|---|---|---|---|
| RCS | 0.00000 | 0.00000 | 0.00000 | |
| WAS | 0.00000 | 0.00000 | 0.00000 | |

GLOBAL REFERENCE

| AREA | CORD | SPAN |
|---|---|---|
| 1.000 | 1.000 | 1.000 |

LOCAL REFERENCE

| AREA | CORD |
|---|---|
| 1.000 | 1.000 |

NUMBER OF SOLUTIONS SELECTED 3

| SOLUTION NO. | ID |
|---|---|
| 1 | SOLN-1 |
| 2 | SOLN-2 |
| 3 | SOLN-3 |

Figure 8.8 - Continued

CONFIGURATION FORCES AND MOMENTS CASE NUMBER 1 ID : ALPHA-VARIATION-FM PAGE 3

SOLUTION NO : 1,ID : SOLN-1 NETWORK NO : 1,ID : UPPER-WING RETAIN ,IMAGE : INPUT

PRESSURE COMPUTATION = UNIFORM ONSET FLOW VECTOR ALPHA = -.57,BETA = 0.00,MACH = 2.000,CALPHA = 0.00,CBETA = 0.00

| | VEL. OPT. | VEL. CORR | AXIS SYS. | PRS. RULE | AREA | VOLUME FLOW | FORCES FX | FY | FZ | MOMENTS MX | MY | MZ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| COL 1 PANEL 1 | B.C. | NONE | RCS | ISEN | .18797 | -.01125 | .00060 | -.00060 | -.01198 | -.00309 | .00538 | -.00042 |
| | | | | LINE | | | .00062 | -.00062 | -.01246 | -.00318 | .00564 | -.00044 |
| | | | | SECO | | | .00061 | -.00061 | -.01215 | -.00314 | .00547 | -.00043 |
| | | | | REDU | | | .00056 | -.00056 | -.01115 | -.00287 | .00502 | -.00039 |
| | | | | SLEN | | | .00068 | -.00068 | -.01353 | -.00342 | .00615 | -.00048 |
| | | | WAS | ISEN | | | .00072 | -.00060 | -.01197 | -.00309 | .00538 | -.00045 |
| | | | | LINE | | | .00075 | -.00062 | -.01246 | -.00317 | .00564 | -.00047 |
| | | | | SECO | | | .00073 | -.00061 | -.01215 | -.00313 | .00547 | -.00046 |
| | | | | REDU | | | .00067 | -.00056 | -.01115 | -.00286 | .00502 | -.00042 |
| | | | | SLEN | | | .00081 | -.00068 | -.01352 | -.00341 | .00615 | -.00051 |
| PANEL 2 | | | RCS | ISEN | .18773 | .00750 | .00059 | .00000 | .01177 | .00253 | -.00942 | -.00013 |
| | | | | LINE | | | .00060 | .00000 | .01194 | .00256 | -.00957 | -.00013 |
| | | | | SECO | | | .00059 | .00000 | .01187 | .00254 | -.00949 | -.00013 |
| | | | | REDU | | | .00064 | .00000 | .01272 | .00272 | -.01018 | -.00014 |
| | | | | SLEN | | | .00057 | .00000 | .01138 | .00244 | -.00914 | -.00012 |
| | | | WAS | ISEN | | | .00047 | .00000 | .01178 | .00253 | -.00942 | -.00010 |
| | | | | LINE | | | .00048 | .00000 | .01195 | .00256 | -.00957 | -.00010 |
| | | | | SECO | | | .00047 | .00000 | .01187 | .00255 | -.00949 | -.00010 |
| | | | | REDU | | | .00051 | .00000 | .01273 | .00272 | -.01018 | -.00011 |
| | | | | SLEN | | | .00046 | .00000 | .01139 | .00244 | -.00914 | -.00010 |
| COLUMN 1 SUM | | | RCS | ISEN | .37570 | -.00375 | .00119 | -.00060 | -.00020 | -.00057 | -.00404 | -.00055 |
| | | | | LINE | | | .00122 | -.00062 | -.00052 | -.00062 | -.00393 | -.00057 |
| | | | | SECO | | | .00120 | -.00061 | -.00029 | -.00059 | -.00402 | -.00056 |
| | | | | REDU | | | .00119 | -.00056 | .00157 | -.00015 | -.00516 | -.00053 |

Figure 8.8 - Continued

| | VEL. OPT. | VEL. CORR | AXIS SYS. | PRS. RULE | AREA | VOLUME FLOW | FORCES FX | FY | FZ | MOMENTS MX | MY | MZ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| COLUMN 1 SUM | B.C. | NONE | RCS | SLEN | .37570 | -.00375 | .00125 | -.00068 | -.00215 | -.00098 | -.00299 | -.00060 |
| | | | WAS | ISEN | | | .00119 | -.00060 | -.00019 | -.00056 | -.00404 | -.00056 |
| | | | | LINE | | | .00123 | -.00062 | -.00051 | -.00061 | -.00393 | -.00057 |
| | | | | SECO | | | .00120 | -.00061 | -.00027 | -.00059 | -.00402 | -.00056 |
| | | | | REDU | | | .00118 | -.00056 | .00158 | -.00014 | -.00516 | -.00053 |
| | | | | SLEN | | | .00127 | -.00068 | -.00213 | -.00097 | -.00299 | -.00061 |
| COL 2 PANEL 1 | | | RCS | ISEN | .08266 | -.00375 | .00033 | -.00033 | -.00658 | -.00458 | .00558 | -.00051 |
| | | | | LINE | | | .00029 | -.00029 | -.00582 | -.00406 | .00498 | -.00045 |
| | | | | SECO | | | .00036 | -.00036 | -.00724 | -.00508 | .00615 | -.00056 |
| | | | | REDU | | | .00021 | -.00021 | -.00428 | -.00292 | .00369 | -.00033 |
| | | | | SLEN | | | .00033 | -.00033 | -.00663 | -.00465 | .00565 | -.00052 |
| | | | WAS | ISEN | | | .00039 | -.00033 | -.00657 | -.00457 | .00558 | -.00055 |
| | | | | LINE | | | .00035 | -.00029 | -.00582 | -.00405 | .00498 | -.00049 |
| | | | | SECO | | | .00043 | -.00036 | -.00724 | -.00508 | .00615 | -.00061 |
| | | | | REDU | | | .00026 | -.00021 | -.00428 | -.00292 | .00369 | -.00036 |
| | | | | SLEN | | | .00040 | -.00033 | -.00663 | -.00465 | .00565 | -.00056 |
| PANEL 2 | | | RCS | ISEN | .06258 | .00250 | .00000 | -.00000 | .00002 | -.00025 | .00005 | .00001 |
| | | | | LINE | | | .00002 | -.00000 | .00031 | -.00007 | -.00022 | .00000 |
| | | | | SECO | | | -.00000 | -.00000 | -.00002 | -.00028 | .00010 | .00001 |
| | | | | REDU | | | .00004 | -.00000 | .00072 | .00021 | -.00061 | -.00001 |
| | | | | SLEN | | | .00000 | -.00000 | .00009 | -.00022 | -.00001 | .00001 |
| | | | WAS | ISEN | | | .00000 | -.00000 | .00002 | -.00025 | .00005 | .00001 |
| | | | | LINE | | | .00001 | -.00000 | .00031 | -.00007 | -.00022 | .00000 |
| | | | | SECO | | | -.00000 | -.00000 | -.00002 | -.00028 | .00010 | .00001 |

Figure 8.8 - Continued

CONFIGURATION FORCES AND MOMENTS — CASE NUMBER 1 ID : ALPHA-VARIATION-FM — PAGE 5

| | VEL. OPT. | VEL. CORR | AXIS SYS. | PRS. RULE | AREA | VOLUME FLOW | FORCES FX | FY | FZ | MOMENTS MX | MY | MZ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| COL 2 PANEL 2 | B.C. | NONE | WAS | REDU | .06258 | .00250 | .00003 | -.00000 | .00072 | .00021 | -.00061 | -.00001 |
| | | | | SLEN | | | .00000 | -.00000 | .00009 | -.00022 | -.00001 | .00001 |
| COLUMN 2 SUM | | | RCS | ISEN | .12523 | -.00125 | .00033 | -.00033 | -.00655 | -.00483 | .00564 | -.00050 |
| | | | | LINE | | | .00031 | -.00029 | -.00552 | -.00413 | .00476 | -.00045 |
| | | | | SECO | | | .00036 | -.00036 | -.00727 | -.00537 | .00625 | -.00055 |
| | | | | REDU | | | .00025 | -.00021 | -.00356 | -.00272 | .00309 | -.00034 |
| | | | | SLEN | | | .00034 | -.00033 | -.00655 | -.00487 | .00564 | -.00050 |
| | | | WAS | ISEN | | | .00040 | -.00033 | -.00655 | -.00482 | .00564 | -.00054 |
| | | | | LINE | | | .00036 | -.00029 | -.00551 | -.00412 | .00476 | -.00049 |
| | | | | SECO | | | .00043 | -.00036 | -.00726 | -.00536 | .00625 | -.00060 |
| | | | | REDU | | | .00029 | -.00021 | -.00356 | -.00271 | .00309 | -.00037 |
| | | | | SLEN | | | .00040 | -.00033 | -.00654 | -.00487 | .00564 | -.00055 |
| NETWORK 1 SUM | | | RCS | ISEN | .50094 | -.00500 | .00152 | -.00093 | -.00675 | -.00539 | .00160 | -.00105 |
| | | | | LINE | | | .00153 | -.00091 | -.00604 | -.00474 | .00083 | -.00102 |
| | | | | SECO | | | .00156 | -.00097 | -.00755 | -.00596 | .00222 | -.00110 |
| | | | | REDU | | | .00144 | -.00077 | -.00199 | -.00286 | -.00207 | -.00087 |
| | | | | SLEN | | | .00158 | -.00101 | -.00869 | -.00585 | .00265 | -.00110 |
| | | | WAS | ISEN | | | .00158 | -.00093 | -.00674 | -.00538 | .00160 | -.00110 |
| | | | | LINE | | | .00159 | -.00091 | -.00602 | -.00473 | .00083 | -.00106 |
| | | | | SECO | | | .00164 | -.00097 | -.00754 | -.00595 | .00222 | -.00116 |
| | | | | REDU | | | .00146 | -.00077 | -.00198 | -.00286 | -.00207 | -.00090 |
| | | | | SLEN | | | .00167 | -.00101 | -.00868 | -.00584 | .00265 | -.00116 |

Figure 8.8 - Continued

CONFIGURATION FORCES AND MOMENTS CASE NUMBER 1 ID : ALPHA-VARIATION-FM PAGE 6

SOLUTION NO : 1,ID : SOLN-1 NETWORK NO : 1,ID : UPPER-WING RETAIN ,IMAGE : 3RD-

PRESSURE COMPUTATION = UNIFORM ONSET FLOW VECTOR ALPHA = -.57,BETA = 0.00,MACH = 2.000,CALPHA = 0.00,CBETA = 0.00

| | | VEL. OPT. | VEL. CORR | AXIS SYS. | PRS. RULE | AREA | VOLUME FLOW | FORCES FX | FY | FZ | MOMENTS MX | MY | MZ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| CONFIG. | 1 SUM | B.C. | NONE | RCS | ISEN | 1.00187 | -.01000 | .00303 | 0.00000 | -.01351 | 0.00000 | .00319 | 0.00000 |
| | | | | | LINE | | | .00305 | 0.00000 | -.01207 | 0.00000 | .00165 | 0.00000 |
| | | | | | SECO | | | .00312 | 0.00000 | -.01510 | 0.00000 | .00444 | 0.00000 |
| | | | | | REDU | | | .00289 | 0.00000 | -.00398 | 0.00000 | -.00415 | 0.00000 |
| | | | | | SLEN | | | .00316 | 0.00000 | -.01738 | 0.00000 | .00531 | 0.00000 |
| | | | | WAS | ISEN | | | .00317 | 0.00000 | -.01348 | 0.00000 | .00319 | 0.00000 |
| | | | | | LINE | | | .00317 | 0.00000 | -.01204 | 0.00000 | .00165 | 0.00000 |
| | | | | | SECO | | | .00327 | 0.00000 | -.01507 | 0.00000 | .00444 | 0.00000 |
| | | | | | REDU | | | .00293 | 0.00000 | -.00395 | 0.00000 | -.00415 | 0.00000 |
| | | | | | SLEN | | | .00334 | 0.00000 | -.01735 | 0.00000 | .00531 | 0.00000 |

Figure 8.8 - Continued

SOLUTION NO : 2,IO : SOLN-2 NETWORK NO : 1,IO : UPPER-WING RETAIN ,IMAGE : INPUT

PRESSURE COMPUTATION = UNIFORM ONSET FLOW VECTOR ALPHA = 0.00,BETA = 0.00,MACH = 2.000,CALPHA = 0.00,CBETA = 0.00

| | VEL. OPT. | VEL. CORR | AXIS SYS. | PRS. RULE | AREA | VOLUME FLOW | FORCES FX | FY | FZ | MOMENTS MX | MY | MZ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| COL 1 PANEL 1 | B.C. | NONE | RCS | ISEN | .18797 | -.01125 | .00052 | -.00052 | -.01035 | -.00267 | .00471 | -.00037 |
| | | | | LINE | | | .00053 | -.00053 | -.01069 | -.00273 | .00489 | -.00038 |
| | | | | SECO | | | .00052 | -.00052 | -.01047 | -.00270 | .00477 | -.00037 |
| | | | | REDU | | | .00048 | -.00048 | -.00970 | -.00250 | .00441 | -.00035 |
| | | | | SLEN | | | .00057 | -.00057 | -.01149 | -.00291 | .00527 | -.00041 |
| | | | WAS | ISEN | | | .00052 | -.00052 | -.01035 | -.00267 | .00471 | -.00037 |
| | | | | LINE | | | .00053 | -.00053 | -.01069 | -.00273 | .00489 | -.00038 |
| | | | | SECO | | | .00052 | -.00052 | -.01047 | -.00270 | .00477 | -.00037 |
| | | | | REDU | | | .00048 | -.00048 | -.00970 | -.00250 | .00441 | -.00035 |
| | | | | SLEN | | | .00057 | -.00057 | -.01149 | -.00291 | .00527 | -.00041 |
| PANEL 2 | | | RCS | ISEN | .18773 | .00750 | .00069 | .00000 | .01398 | .00298 | -.01112 | -.00015 |
| | | | | LINE | | | .00071 | .00000 | .01412 | .00302 | -.01132 | -.00015 |
| | | | | SECO | | | .00070 | .00000 | .01402 | .00301 | -.01123 | -.00015 |
| | | | | REDU | | | .00076 | .00000 | .01518 | .00324 | -.01215 | -.00016 |
| | | | | SLEN | | | .00067 | .00000 | .01335 | .00286 | -.01073 | -.00014 |
| | | | WAS | ISEN | | | .00069 | .00000 | .01388 | .00298 | -.01112 | -.00015 |
| | | | | LINE | | | .00071 | .00000 | .01412 | .00302 | -.01132 | -.00015 |
| | | | | SECO | | | .00070 | .00000 | .01402 | .00301 | -.01123 | -.00015 |
| | | | | REDU | | | .00076 | .00000 | .01518 | .00324 | -.01215 | -.00016 |
| | | | | SLEN | | | .00067 | .00000 | .01335 | .00286 | -.01073 | -.00014 |
| COLUMN 1 SUM | | | RCS | ISEN | .37570 | -.00375 | .00121 | -.00052 | .00353 | .00031 | -.00641 | -.00052 |
| | | | | LINE | | | .00124 | -.00053 | .00343 | .00029 | -.00644 | -.00053 |
| | | | | SECO | | | .00122 | -.00052 | .00355 | .00031 | -.00646 | -.00052 |
| | | | | REDU | | | .00124 | -.00048 | .00549 | .00074 | -.00774 | -.00051 |

Figure 8.8 - Continued

CONFIGURATION FORCES AND MOMENTS  CASE NUMBER 1 ID : ALPHA-VARIATION-FM  PAGE 8

| | VEL. OPT. | VEL. CORR | AXIS SYS. | PRS. RULE | AREA | VOLUME FLOW | FORCES FX | FY | FZ | MOMENTS MX | MY | MZ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| COLUMN 1 SUM | B.C. | NONE | RCS | SLEN | .37570 | -.00375 | .00124 | -.00057 | .00185 | -.00005 | -.00545 | -.00055 |
| | | | WAS | ISEN | | | .00121 | -.00052 | .00353 | .00031 | -.00641 | -.00052 |
| | | | | LINE | | | .00124 | -.00053 | .00343 | .00029 | -.00644 | -.00053 |
| | | | | SECO | | | .00122 | -.00052 | .00355 | .00031 | -.00646 | -.00052 |
| | | | | REDU | | | .00124 | -.00048 | .00549 | .00074 | -.00774 | -.00051 |
| | | | | SLEN | | | .00124 | -.00057 | .00185 | -.00005 | -.00545 | -.00055 |
| COL 2 PANEL 1 | | | RCS | ISEN | .06266 | -.00375 | .00029 | -.00029 | -.00577 | -.00401 | .00492 | -.00045 |
| | | | | LINE | | | .00025 | -.00025 | -.00509 | -.00354 | .00436 | -.00040 |
| | | | | SECO | | | .00031 | -.00031 | -.00626 | -.00437 | .00533 | -.00048 |
| | | | | REDU | | | .00019 | -.00019 | -.00385 | -.00263 | .00333 | -.00030 |
| | | | | SLEN | | | .00029 | -.00029 | -.00573 | -.00401 | .00490 | -.00045 |
| | | | WAS | ISEN | | | .00029 | -.00029 | -.00577 | -.00401 | .00492 | -.00045 |
| | | | | LINE | | | .00025 | -.00025 | -.00509 | -.00354 | .00436 | -.00040 |
| | | | | SECO | | | .00031 | -.00031 | -.00626 | -.00437 | .00533 | -.00048 |
| | | | | REDU | | | .00019 | -.00019 | -.00385 | -.00263 | .00333 | -.00030 |
| | | | | SLEN | | | .00029 | -.00029 | -.00573 | -.00401 | .00490 | -.00045 |
| PANEL 2 | | | RCS | ISEN | .06258 | .00250 | .00006 | -.00000 | .00113 | .00055 | -.00101 | -.00003 |
| | | | | LINE | | | .00006 | -.00000 | .00118 | .00058 | -.00106 | -.00003 |
| | | | | SECO | | | .00006 | -.00000 | .00113 | .00055 | -.00101 | -.00003 |
| | | | | REDU | | | .00007 | -.00000 | .00149 | .00079 | -.00136 | -.00004 |
| | | | | SLEN | | | .00005 | -.00000 | .00097 | .00044 | -.00086 | -.00002 |
| | | | WAS | ISEN | | | .00006 | -.00000 | .00113 | .00055 | -.00101 | -.00003 |
| | | | | LINE | | | .00006 | -.00000 | .00118 | .00058 | -.00106 | -.00003 |
| | | | | SECO | | | .00006 | -.00000 | .00113 | .00055 | -.00101 | -.00003 |

Figure 8.8 - Continued

CONFIGURATION FORCES AND MOMENTS  CASE NUMBER 1 ID : ALPHA-VARIATION-FM  PAGE 9

| | VEL. OPT. | VEL. CORR | AXIS SYS. | PRS. RULE | AREA | VOLUME FLOW | FORCES FX | FY | FZ | MOMENTS MX | MY | MZ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| COL 2 PANEL 2 | B.C. | NONE | WAS | REDU | .06258 | .00250 | .00007 | -.00000 | .00149 | .00079 | -.00136 | -.00004 |
| | | | | SLEN | | | .00005 | -.00000 | .00097 | .00044 | -.00086 | -.00002 |
| COLUMN 2 SUM | | | RCS | ISEN | .12523 | -.00125 | .00035 | -.00029 | -.00465 | -.00345 | .00391 | -.00047 |
| | | | | LINE | | | .00031 | -.00025 | -.00391 | -.00296 | .00330 | -.00042 |
| | | | | SECO | | | .00037 | -.00031 | -.00513 | -.00382 | .00432 | -.00051 |
| | | | | REDU | | | .00027 | -.00019 | -.00236 | -.00185 | .00197 | -.00034 |
| | | | | SLEN | | | .00033 | -.00029 | -.00477 | -.00357 | .00404 | -.00047 |
| | | | WAS | ISEN | | | .00035 | -.00029 | -.00465 | -.00345 | .00391 | -.00047 |
| | | | | LINE | | | .00031 | -.00025 | -.00391 | -.00296 | .00330 | -.00042 |
| | | | | SECO | | | .00037 | -.00031 | -.00513 | -.00382 | .00432 | -.00051 |
| | | | | REDU | | | .00027 | -.00019 | -.00236 | -.00185 | .00197 | -.00034 |
| | | | | SLEN | | | .00033 | -.00029 | -.00477 | -.00357 | .00404 | -.00047 |
| NETWORK 1 SUM | | | RCS | ISEN | .50094 | -.00500 | .00156 | -.00081 | -.00112 | -.00314 | -.00250 | -.00099 |
| | | | | LINE | | | .00155 | -.00079 | -.00048 | -.00267 | -.00314 | -.00096 |
| | | | | SECO | | | .00159 | -.00084 | -.00158 | -.00351 | -.00214 | -.00104 |
| | | | | REDU | | | .00151 | -.00068 | .00313 | -.00110 | -.00577 | -.00085 |
| | | | | SLEN | | | .00158 | -.00086 | -.00291 | -.00363 | -.00141 | -.00102 |
| | | | WAS | ISEN | | | .00156 | -.00081 | -.00112 | -.00314 | -.00250 | -.00099 |
| | | | | LINE | | | .00155 | -.00079 | -.00048 | -.00267 | -.00314 | -.00096 |
| | | | | SECO | | | .00159 | -.00084 | -.00158 | -.00351 | -.00214 | -.00104 |
| | | | | REDU | | | .00151 | -.00068 | .00313 | -.00110 | -.00577 | -.00085 |
| | | | | SLEN | | | .00158 | -.00086 | -.00291 | -.00363 | -.00141 | -.00102 |

Figure 8.8 - Continued

CONFIGURATION FORCES AND MOMENTS CASE NUMBER 1 ID : ALPHA-VARIATION-FM PAGE 10

SOLUTION NO : 2,ID : SOLN-2 NETWORK NO : 1,ID : UPPER-WING RETAIN ,IMAGE : 3RD-

PRESSURE COMPUTATION = UNIFORM ONSET FLOW VECTOR ALPHA = 0.00,BETA = 0.00,MACH = 2.000,CALPHA = 0.00,CBETA = 0.00

| | VEL. OPT. | VEL. CORR | AXIS SYS. | PRS. RULE | AREA | VOLUME FLOW | FORCES FX | FY | FZ | MOMENTS MX | MY | MZ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| CONFIG. | 2 SUM | B.C. | NONE | RCS | ISEN | 1.09187 | -.01000 | .00311 | 0.00000 | -.00223 | 0.00000 | -.00501 | 0.00000 |
| | | | | | LINE | | | .00311 | 0.00000 | -.00096 | 0.00000 | -.00627 | 0.00000 |
| | | | | | SECO | | | .00319 | 0.00000 | -.00315 | 0.00000 | -.00429 | 0.00000 |
| | | | | | REDU | | | .00302 | 0.00000 | .00626 | 0.00000 | -.01153 | 0.00000 |
| | | | | | SLEN | | | .00315 | 0.00000 | -.00583 | 0.00000 | -.00282 | 0.00000 |
| | | | | WAS | ISEN | | | .00311 | 0.00000 | -.00223 | 0.00000 | -.00501 | 0.00000 |
| | | | | | LINE | | | .00311 | 0.00000 | -.00096 | 0.00000 | -.00627 | 0.00000 |
| | | | | | SECO | | | .00319 | 0.00000 | -.00315 | 0.00000 | -.00429 | 0.00000 |
| | | | | | REDU | | | .00302 | 0.00000 | .00626 | 0.00000 | -.01153 | 0.00000 |
| | | | | | SLEN | | | .00315 | 0.00000 | -.00583 | 0.00000 | -.00282 | 0.00000 |

Figure 8.8 - Continued

SOLUTION NO : 3,ID : SOLN-3 NETWORK NO : 1,ID : UPPER-WING RETAIN ,IMAGE : INPUT

PRESSURE COMPUTATION = UNIFORM ONSET FLOW VECTOR ALPHA = .57,BETA = 0.00,MACH = 2.000,CALPHA = 0.00,CBETA = 0.00

| | VEL. OPT. | VEL. CORR | AXIS SYS. | PRS. RULE | AREA | VOLUME FLOW | FORCES FX | FY | FZ | MOMENTS MX | MY | MZ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| COL 1 PANEL 1 | B.C. | NONE | RCS | ISEN | .18797 | -.01125 | .00043 | -.00043 | -.00861 | -.00223 | .00398 | -.00031 |
| | | | | LINE | | | .00044 | -.00044 | -.00885 | -.00227 | .00410 | -.00032 |
| | | | | SECO | | | .00043 | -.00043 | -.00870 | -.00224 | .00402 | -.00031 |
| | | | | REDU | | | .00041 | -.00041 | -.00812 | -.00210 | .00375 | -.00029 |
| | | | | SLEN | | | .00047 | -.00047 | -.00943 | -.00240 | .00439 | -.00034 |
| | | | WAS | ISEN | | | .00034 | -.00043 | -.00862 | -.00223 | .00398 | -.00029 |
| | | | | LINE | | | .00035 | -.00044 | -.00885 | -.00227 | .00410 | -.00030 |
| | | | | SECO | | | .00035 | -.00043 | -.00870 | -.00225 | .00402 | -.00029 |
| | | | | REDU | | | .00032 | -.00041 | -.00812 | -.00210 | .00375 | -.00027 |
| | | | | SLEN | | | .00038 | -.00047 | -.00944 | -.00241 | .00439 | -.00032 |
| PANEL 2 | | | RCS | ISEN | .18773 | .00750 | .00080 | .00000 | .01604 | .00344 | -.01286 | -.00017 |
| | | | | LINE | | | .00082 | .00000 | .01637 | .00350 | -.01314 | -.00017 |
| | | | | SECO | | | .00081 | .00000 | .01626 | .00348 | -.01303 | -.00017 |
| | | | | REDU | | | .00089 | .00000 | .01779 | .00380 | -.01425 | -.00019 |
| | | | | SLEN | | | .00077 | .00000 | .01534 | .00328 | -.01234 | -.00016 |
| | | | WAS | ISEN | | | .00096 | .00000 | .01603 | .00344 | -.01286 | -.00021 |
| | | | | LINE | | | .00098 | .00000 | .01636 | .00350 | -.01314 | -.00021 |
| | | | | SECO | | | .00098 | .00000 | .01625 | .00348 | -.01303 | -.00021 |
| | | | | REDU | | | .00107 | .00000 | .01778 | .00380 | -.01425 | -.00023 |
| | | | | SLEN | | | .00092 | .00000 | .01533 | .00327 | -.01234 | -.00020 |
| COLUMN 1 SUM | | | RCS | ISEN | .37570 | -.00375 | .00123 | -.00043 | .00742 | .00121 | -.00888 | -.00048 |
| | | | | LINE | | | .00126 | -.00044 | .00753 | .00123 | -.00903 | -.00049 |
| | | | | SECO | | | .00125 | -.00043 | .00756 | .00124 | -.00900 | -.00049 |
| | | | | REDU | | | .00130 | -.00041 | .00967 | .00170 | -.01050 | -.00048 |

Figure 8.8 - Continued

CONFIGURATION FORCES AND MOMENTS  CASE NUMBER 1 ID : ALPHA-VARIATION-FM  PAGE 12

| | VEL. OPT. | VEL. CORR | AXIS SYS. | PRS. RULE | AREA | VOLUME FLOW | FORCES FX | FY | FZ | MOMENTS MX | MY | MZ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| COLUMN 1 SUM | H.C. | NONE | RCS | SLEN | .37570 | -.00375 | .00124 | -.00047 | .00591 | .00087 | -.00795 | -.00050 |
| | | | WAS | ISEN | | | .00131 | -.00043 | .00741 | .00121 | -.00888 | -.00049 |
| | | | | LINE | | | .00134 | -.00044 | .00751 | .00122 | -.00903 | -.00051 |
| | | | | SECO | | | .00132 | -.00043 | .00755 | .00124 | -.00900 | -.00050 |
| | | | | REDU | | | .00139 | -.00041 | .00966 | .00170 | -.01050 | -.00050 |
| | | | | SLEN | | | .00130 | -.00047 | .00589 | .00087 | -.00795 | -.00051 |
| COL 2 PANEL 1 | | | RCS | ISEN | .06266 | -.00375 | .00025 | -.00025 | -.00493 | -.00341 | .00421 | -.00038 |
| | | | | LINE | | | .00022 | -.00022 | -.00434 | -.00301 | .00373 | -.00034 |
| | | | | SECO | | | .00026 | -.00026 | -.00527 | -.00367 | .00450 | -.00041 |
| | | | | REDU | | | .00017 | -.00017 | -.00336 | -.00230 | .00292 | -.00026 |
| | | | | SLEN | | | .00024 | -.00024 | -.00483 | -.00337 | .00414 | -.00038 |
| | | | WAS | ISEN | | | .00020 | -.00025 | -.00493 | -.00342 | .00421 | -.00035 |
| | | | | LINE | | | .00017 | -.00022 | -.00434 | -.00301 | .00373 | -.00031 |
| | | | | SECO | | | .00021 | -.00026 | -.00527 | -.00367 | .00450 | -.00037 |
| | | | | REDU | | | .00013 | -.00017 | -.00337 | -.00230 | .00292 | -.00024 |
| | | | | SLEN | | | .00019 | -.00024 | -.00483 | -.00338 | .00414 | -.00034 |
| PANEL 2 | | | RCS | ISEN | .06258 | .00250 | .00011 | -.00000 | .00215 | .00129 | -.00200 | -.00006 |
| | | | | LINE | | | .00010 | -.00000 | .00209 | .00125 | -.00193 | -.00006 |
| | | | | SECO | | | .00011 | -.00000 | .00218 | .00131 | -.00202 | -.00007 |
| | | | | REDU | | | .00012 | -.00000 | .00238 | .00144 | -.00221 | -.00007 |
| | | | | SLEN | | | .00009 | -.00000 | .00185 | .00110 | -.00171 | -.00005 |
| | | | WAS | ISEN | | | .00013 | -.00000 | .00215 | .00129 | -.00200 | -.00008 |
| | | | | LINE | | | .00013 | -.00000 | .00209 | .00125 | -.00193 | -.00008 |
| | | | | SECO | | | .00013 | -.00000 | .00218 | .00131 | -.00202 | -.00008 |

Figure 8.8 - Continued

| | VEL. OPT. | VEL. CORR | AXIS SYS. | PRS. RULE | AREA | VOLUME FLOW | FORCES FX | FY | FZ | MOMENTS MX | MY | MZ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| COL 2 PANEL 2 | B.C. | NONE | WAS | REDU | .06258 | .00250 | .00014 | -.00000 | .00238 | .00144 | -.00221 | -.00009 |
| | | | | SLEN | | | .00011 | -.00000 | .00184 | .00110 | -.00171 | -.00007 |
| COLUMN 2 SUM | | | RCS | ISEN | .12523 | -.00125 | .00035 | -.00025 | -.00278 | -.00212 | .00222 | -.00045 |
| | | | | LINE | | | .00032 | -.00022 | -.00225 | -.00176 | .00179 | -.00040 |
| | | | | SECO | | | .00037 | -.00026 | -.00309 | -.00236 | .00248 | -.00047 |
| | | | | REDU | | | .00029 | -.00017 | -.00099 | -.00086 | .00071 | -.00033 |
| | | | | SLEN | | | .00033 | -.00024 | -.00299 | -.00227 | .00243 | -.00043 |
| | | | WAS | ISEN | | | .00033 | -.00025 | -.00278 | -.00213 | .00222 | -.00042 |
| | | | | LINE | | | .00030 | -.00022 | -.00225 | -.00176 | .00179 | -.00038 |
| | | | | SECO | | | .00034 | -.00026 | -.00309 | -.00236 | .00248 | -.00045 |
| | | | | REDU | | | .00028 | -.00017 | -.00099 | -.00087 | .00071 | -.00032 |
| | | | | SLEN | | | .00030 | -.00024 | -.00299 | -.00228 | .00243 | -.00041 |
| NETWORK 1 SUM | | | RCS | ISEN | .50094 | -.00500 | .00159 | -.00068 | .00464 | -.00091 | -.00666 | -.00093 |
| | | | | LINE | | | .00158 | -.00066 | .00528 | -.00053 | -.00724 | -.00089 |
| | | | | SECO | | | .00162 | -.00070 | .00447 | -.00112 | -.00652 | -.00096 |
| | | | | REDU | | | .00158 | -.00057 | .00869 | .00084 | -.00979 | -.00082 |
| | | | | SLEN | | | .00157 | -.00071 | .00292 | -.00140 | -.00551 | -.00093 |
| | | | WAS | ISEN | | | .00163 | -.00068 | .00463 | -.00092 | -.00666 | -.00092 |
| | | | | LINE | | | .00163 | -.00066 | .00526 | -.00054 | -.00724 | -.00089 |
| | | | | SECO | | | .00166 | -.00070 | .00445 | -.00113 | -.00652 | -.00095 |
| | | | | REDU | | | .00167 | -.00057 | .00867 | .00083 | -.00979 | -.00082 |
| | | | | SLEN | | | .00160 | -.00071 | .00291 | -.00141 | -.00551 | -.00092 |

Figure 8.8 - Continued

CONFIGURATION FORCES AND MOMENTS CASE NUMBER 1 ID : ALPHA-VARIATION-FM PAGE 14

SOLUTION NO : 3,ID : SOLN-3 NETWORK NO : 1,ID : UPPER-WING RETAIN ,IMAGE : 3RD-

PRESSURE COMPUTATION = UNIFORM ONSET FLOW VECTOR ALPHA = .57,BETA = 0.00,MACH = 2.000,CALPHA = 0.00,CBETA = 0.00

| | VEL. OPT. | VEL. CORR | AXIS SYS. | PRS. RULE | AREA | VOLUME FLOW | FORCES FX | FY | FZ | MOMENTS MX | MY | MZ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| CONFIG. | 3 SUM | B.C. | NONE | RCS | ISEN | 1.00187 | -.01000 | .00317 | 0.00000 | .00929 | 0.00000 | -.01332 | 0.00000 |
| | | | | | LINE | | | .00316 | 0.00000 | .01055 | 0.00000 | -.01448 | 0.00000 |
| | | | | | SECO | | | .00324 | 0.00000 | .00894 | 0.00000 | -.01305 | 0.00000 |
| | | | | | REDU | | | .00317 | 0.00000 | .01737 | 0.00000 | -.01957 | 0.00000 |
| | | | | | SLEN | | | .00314 | 0.00000 | .00584 | 0.00000 | -.01103 | 0.00000 |
| | | | | WAS | ISEN | | | .00327 | 0.00000 | .00925 | 0.00000 | -.01332 | 0.00000 |
| | | | | | LINE | | | .00327 | 0.00000 | .01052 | 0.00000 | -.01448 | 0.00000 |
| | | | | | SECO | | | .00333 | 0.00000 | .00890 | 0.00000 | -.01305 | 0.00000 |
| | | | | | REDU | | | .00334 | 0.00000 | .01734 | 0.00000 | -.01957 | 0.00000 |
| | | | | | SLEN | | | .00320 | 0.00000 | .00581 | 0.00000 | -.01103 | 0.00000 |

Figure 8.8 - Continued

CONFIGURATION FORCES AND MOMENTS CASE NUMBER 2 ID : ACCUMULATION-CASE-01 PAGE 15

SOLUTION NO : 1,ID : SOLN-1 NETWORK NO : 1,ID : UPPER-WING RETAIN ,IMAGE : 3RD-

PRESSURE COMPUTATION = UNIFORM ONSET FLOW VECTOR ALPHA = -.57,BETA = 0.00,MACH = 2.000,CALPHA = 0.00,CBETA = 0.00

| | VEL. OPT. | VEL. CORR | AXIS SYS. | PRS. RULE | AREA | VOLUME FLOW | FORCES FX | FY | FZ | MOMENTS MX | MY | MZ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| ACCUMULATION SUM | H.C. | NONE | RCS | ISEN | 1.00187 | -.01000 | .00303 | 0.00000 | -.01351 | 0.00000 | .00319 | 0.00000 |
| | | | WAS | | | | .00317 | 0.00000 | -.01348 | 0.00000 | .00319 | 0.00000 |

Figure 8.8 - Continued

```
**************************************************
*                                                *
*   PROGRAM COP     VERSION 1.0        IS FINISHED.  *
*   DATE OF RUN IS  05/16/80                     *
*   TIME OF RUN IS  10.08.14                     *
*                                                *
**************************************************

    CP SECONDS USED BY COP          =       1.0390
```

Figure 8.8 - Concluded

```
**************************************************
*                                                *
*   PROGRAM PPP     VERSION 1.0        NOW RUNNING.  *
*   THE PROGRAM IS PART OF THE PAN AIR SYSTEM     *
*   DATE OF RUN IS  06/05/80                      *
*   TIME OF RUN IS  22.06.38                      *
*                                                *
**************************************************

    DATA BASES TO BE USED

    DEFAULT   ACTUAL
    NAME      NAME      LOCATION        GENERATED BY
    -------   -------   ------ ------   ------- ------ --------
    DIP       DIPPKB    FAE8RP3 PKB
          MD  DIPMD     FAE8RP3 PANAIR
                                        DIP    1.0     06/03/80
                                        RID = VALIDATION CASE 1, INSTALLATION CASE 1 /
                                        PID =    =   SIMPLE DELTA WING WITH THICKNESS
                                        UID =    RALPH L. CARMICHAEL NASA/AMES - KEN SIDWELL /BOEING
```

8.9 - Sample PPP output.

```
RID  = INSTALLATION CASE 1, VALIDATION CASE 1 /

PID

UID

  OPTIONS SELECTED ARE
  --------------------

  GEOMETRY DATA FROM DGO       = 1
  POINT DATA FROM PDP          = 1
  CONFIGURATION DATA FROM CDP = 1

        1 = SELECTED
        0 = NOT SELECTED



  GEOMETRY DATA IS WRITTEN OUT ON TAPE 9(IF SELECTED)
  POINT DATA IS WRITTEN OUT ON TAPE 10(IF SELECTED)
  CONFIGURATION DATA IS WRITTEN OUT ON TAPE 11(IF SELECTED)

DGG       DGGPKB    FAEBRP3 PKB
      MD  DGGMD     FAEBRP3 PANAIR
                                DGG    A01     06/03/80
                                RID = VALIDATION CASE 1, INSTALLATION CASE 1 /
                                PID =    =   SIMPLE DELTA WING WITH THICKNESS
                                UID =    RALPH L. CARMICHAEL NASA/AMES - KEN SIDWELL /BOEING
PDP       PDPPKB    FAEBRP3 PKB
      MD  PDPMD     FAEBRP3 PANAIR
                                PDP    1.0     06/03/80
                                RID = VALIDATION CASE 1, INSTALLATION CASE 1 /
                                PID =    =   SIMPLE DELTA WING WITH THICKNESS
                                UID =    RALPH L. CARMICHAEL NASA/AMES - KEN SIDWELL /BOEING
CDP       CDPPKB    FAEBRP3 PKB
      MD  CDPMD     FAEBRP3 PANAIR
                                CDP    1.0     06/03/80
                                RID = VALIDATION CASE 1, INSTALLATION CASE 1 /
                                PID =    =   SIMPLE DELTA WING WITH THICKNESS
                                UID =    RALPH L. CARMICHAEL NASA/AMES - KEN SIDWELL /BOEING
```

```
                    RID  = INSTALLATION CASE 1, VALIDATION CASE 1 /

                    PID

                    UID

        (GEOMETRY DATA PLOT FILE FORMAT - TAPE 9)

RECORD
SET(S)/
SUBSET(S)
--------
  1-A   NETWORK GEOMETRY FROM DQG DATA BASE
  1-B   RID
  1-C   PID
  1-D   UID
  2     *START      (START OF DQG DATA)
  3     $GLOBAL DATA
  3-1   DATE (YR/MO/DATE)
  3-2   AMACH,CALPHA,CBETA,NUMPOS,NNET
  3-3   POSNRM(I.E. NORMAL TO 1ST AND 2ND PLANES NORMAL TO POS)
  3-4   POSLOC(I.E. COORDS OF POINT COMMON TO 1ST AND 2ND PLANES)
  3-5   NETPPP,NETID(I.E. NETWORK INDEX AND ID, 2 NETWORKS/RECORD SUBSET)
  4     RUN NAME FOR DQG DATA
  5     SEQ NO   ROW NO   COL NO   NET NO   X   Y   Z
           .        .        .        .     .   .   .
           .        .        .        .     .   .   .
           .        .        .        .     .   .   .
        (REPEAT 4 AND 5 ABOVE FOR EACH SELECTED NETWORK)
  6     *END        (END OF DQG DATA)

        RUN NAME IDENTIFICATION FOR GEOMETRY DATA FROM DQG
        --------------------------------------------------

 DQG  NETWK  NO.   NO.   NETWK
 ID   NO.    ROWS  COLS  ID
 ---  -----  ----  ----  -----

 D    XXX    XX    XX    (20 CHARACTERS A/N)
```

8.9 - Continued

```
          RID  = INSTALLATION CASE 1, VALIDATION CASE 1 /

          PID

          UID

---------- G L O B A L   D A T A ----------

     $GLOBAL DATA
      VALIDATION CASE 1, INSTALLATION CASE 1 /
         =   SIMPLE DELTA WING WITH THICKNESS
         RALPH L. CARMICHAEL NASA/AMES - KEN SIDWELL /BOEING
     DATE (YR/MO/DATE)              06/03/80
     MACH NUMBER                        2.000
     ANGLE OF ATTACK(DEGREES)           0.000
     ANGLE OF SIDESLIP(DEGREES)         0.000
     NUMBER OF PLANES OF SYMMETRY           2
          =0  NO PLANES OF SYMMETRY
          =1  ONE PLANE OF SYMMETRY
          =2  TWO PLANES OF SYMMETRY
     NUMBER OF NETWORKS                     1

     POSITION NORMALS       0.00000   1.00000   0.00000   0.00000   0.00000   1.00000

     POSITION LOCATIONS     0.00000   0.00000   0.00000


SEQ  NETWORK
NO.  ID
  1 UPPER-WING
  0    1   3   3  UPPER-WING
```

8.9 - Continued

```
RID  = INSTALLATION CASE 1, VALIDATION CASE 1 /

PID

UID

  PPP SELECTION OPTIONS FOR POINT DATA FROM PDP ARE
  -------------------------------------------------

  NUMBER OF CASES      =   1
  NUMBER OF SOLUTIONS  =   0
  NUMBER OF NETWORKS   =   1
       0-USE DEFAULT VALUE FROM PDP
   NOT 0-PPP SELECTION QUANTITY
  GRID DIRECTION       =   1
       1-BY COLUMNS
       2-BY ROWS
  POINT TYPE           =   1
       0-ORIGINAL SELECTION(DEFAULT)
       1-CONTROL POINTS
       2-GRID POINTS

 (POINT DATA PLOT FILE FORMAT - TAPE 10)

RECORD
SET(S)/
SUBSET(S)
--------
  1     (6F10.5)          (DATA FORMAT)
  2     PDP PLOT TITLES CONSISTING OF 4 LINES OF INFORMATION
  2-1   $POINT DATA FROM PDP DATA BASE
  2-2   $( RUN ID )
  2-3   $( PROBLEM ID )
  2-4   $( USER ID )
  3     *RUN 40           (IDENTIFIES RUN NAME MAX LENGTH 40)
  4     $GLOBAL DATA
  4-1   DATE (YR/MO/DATE)
  4-2   AMACH,CALPHA,CBETA,NUMPOS,NNET,NSOL,NCASE
  4-3   POSNRM(I.E. NORMAL TO 1ST AND 2ND PLANES NORMAL TO POS)
  4-4   POSLOC(I.E. COORDS OF POINT COMMON TO 1ST AND 2ND PLANES)
  4-5   NETPPP,NETID(I.E. NETWORK INDEX AND ID, 2 NETWORKS/RECORD SUBSET)
  4-6   ALPHA(ANGLE OF ATTACK FOR EACH SOLUTION)
  4-7   BETA(ANGLE OF SIDESLIP FOR EACH SOLUTION)
  4-8   SOLUTION LIST AND ID, 2 SOLUTIONS/RECORD SUBSET
  4-9   CASE LIST AND ID, 2 CASES/RECORD SUBSET
  5     PDP PARAMETER NAME LIST IN ORDER OF DATA STORAGE
  6     RUN NAME FOR PDP DATA(MAX LENGTH 40)
  7     POINT DATA FROM PDP IN ORDER OF PARAMETER NAME LIST
        (REPEAT 6 AND 7 ABOVE FOR ALL SELECTIONS)
  8     *EOF              (END OF PDP DATA)
```

8.9 - Continued

RID = INSTALLATION CASE 1, VALIDATION CASE 1 /

PID

UID

RUN NAME IDENTIFICATION FOR POINT DATA FROM PDP

| PDP ID | CASE NO. | SOL NO. | SEQ NO. | SURF | VEL COMP | PRESS COMP | VEL CORR | NETWK ID | IMAGE | POINT TYPE | ROW/ COL | COL* | SEQ* NO. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| P | XX | XXX | 99 | UPPE/1 | BOUN/1 | UNIF/1 | NONE/0 | NXXX | INP/1 | CENT/1 | RXX | CXX | XXX |
| | | | | LOWE/2 | VIC/2 | LOCA/2 | SA1/1 | | 1ST/2 | EDGE/2 | CXX | | |
| | | | | UPLO/3 | | COMP/3 | SA2/2 | | 2ND/3 | ADDI/3 | | | |
| | | | | LOUP/4 | | | | | 3RD/4 | GRID/4 | | | |
| | | | | AVER/5 | | | | | | | | | |

* USED ONLY FOR THE SECOND RUN NAME.

NOTE: THE PDP PLOT FILE HAS 2 SIMILIAR RUN NAMES FOR EACH DATASET OPTION,
FIRST RUN NAME IS 38 CHARACTERS IN LENGTH WITH HOLLERITH IDENTIFIERS REPRESENTING DATA(I.E. HOLLERITH/INTEGER)
SECOND RUN NAME IS 44 CHARACTERS IN LENGTH WITH ASSOCIATED INTEGER IDENTIFIERS FOR DATA(I.E. HOLLERITH/INTEGER)

```
RID  = INSTALLATION CASE 1, VALIDATION CASE 1 /

PID

UID

---------------------------- G L O B A L   D A T A ----------------------------

 VALIDATION CASE 1, INSTALLATION CASE 1 /
    =   SIMPLE DELTA WING WITH THICKNESS
    RALPH L. CARMICHAEL NASA/AMES - KEN SIDWELL /BOEING
DATE (YR/MO/DATE)              06/03/80
MACH NUMBER                        2.000
ANGLE OF ATTACK(DEGREES)           0.000
ANGLE OF SIDESLIP(DEGREES)         0.000
NUMBER OF PLANES OF SYMMETRY           2
     =0  NO PLANES OF SYMMETRY
     =1  ONE PLANE OF SYMMETRY
     =2  TWO PLANES OF SYMMETRY
NUMBER OF NETWORKS                     1
NUMBER OF SOLUTIONS                    3
NUMBER OF CASES                        2

POSITION NORMALS       0.00000   1.00000   0.00000   0.00000   0.00000   1.00000

POSITION LOCATIONS     0.00000   0.00000   0.00000

ALPHA VALUES(DEGREES)

   -.57295   0.00000    .57295

BETA VALUES(DEGREES)

   0.00000   0.00000   0.00000

PLANE 1 WITH SYMMETRIC  FLOW

PLANE 2 WITH ASYMMETRIC FLOW
```

8.9 - Continued

RID = INSTALLATION CASE 1, VALIDATION CASE 1 /

PID

UID

| SEQ NO | NETWORK ID |
|---|---|
| 1 | UPPER-WING |

| SEQ NO | SOLUTION ID |
|---|---|
| 1 | SOLN-1 |
| 3 | SOLN-3 |

| SEQ NO | SOLUTION ID |
|---|---|
| 2 | SOLN-2 |

| SEQ NO | CASE ID |
|---|---|
| 1 | ZERO-ALPHA |

| SEQ NO | CASE ID |
|---|---|
| 2 | ALPHA-VARIATION-SF |

8.9 - Continued

RID = INSTALLATION CASE 1, VALIDATION CASE 1 /

PID

UID

SURFACE FLOW PROPERTIES - CASE NUMBER 2

NUMBER OF NETWORKS SELECTED 1

NUMBER OF SOLUTIONS SELECTED 3

POINT TYPES SELECTED PANEL CENTER CONTROL POINTS

SURFACES SELECTED UPPE LOWE

VELOCITY COMPUTATION OPTION(S) BOUN

VELOCITY CORRECTION OPTION(S)

| NONE | SA1 | SA2 |
|---|---|---|
| * | 0 | 0 |

PRESSURE COMPUTATION OPTION(S) UNIF

********** FLOW QUANTITIES SELECTED **********

| | | | | | | |
|---|---|---|---|---|---|---|
| ROW | COLUMN | X | Y | Z | PWX | MORE |
| * | * | * | * | * | * | |
| PWY | PWZ | WX | WY | WZ | WMAG | MORE |
| * | * | * | * | * | * | |
| WN | PVX | PVY | PVZ | VX | VY | MORE |
| * | * | * | * | * | * | |
| VZ | VMAG | PHI | PHIT | MLISEN | MLLINE | MORE |
| * | * | * | * | * | * | |
| MLSECO | MLREDU | MLSLEN | CPISEN | CPLINE | CPSECO | MORE |
| * | * | * | * | * | * | |
| CPREDU | CPSLEN | GMUX | GMUY | GMUZ | PSI | MORE |
| * | * | * | * | * | * | |
| SINGS | SINGD | SPDMAX | SPDCRT | CPVAC | | |
| * | * | * | * | * | | |

* = FLOW QUANTITIES DATA SELECTED
0 = FLOW QUANTITIES DATA NOT SELECTED

8.9 - Continued

RID = INSTALLATION CASE 1, VALIDATION CASE 1 /

PID

UID

SURFACE FLOW PROPERTIES AT PANEL CENTER CONTROL POINTS CASE NUMBER : 2 ID : ALPHA-VARIATION-SF

SOLUTION NO : 1 NETWORK NO : 1,ID : UPPER-WING ,IMAGE :INPUT

PRESSURE COMP UNIF VELOCITY COMPUTATON BOUN VELOCITY CORRECTION NONE

PDP PARAMETER NAME LIST IN ORDER OF DATA STORAGE

| | | | | | | |
|---|---|---|---|---|---|---|
| X | Y | Z | PWX | PWY | PWZ | MORE |
| WX | WY | WZ | WMAG | WN | PVX | MORE |
| PVY | PVZ | VX | VY | VZ | VMAG | MORE |
| PHI | PHIT | MLISEN | MLLINE | MLSECO | MLREDU | MORE |
| MLSLEN | CPISEN | CPLINE | CPSECO | CPREDU | CPSLEN | MORE |
| GMUX | GMUY | GMUZ | PSI | SINGS | SINGD | MORE |
| SPDMAX | SPDCRT | CPVAC | | | | |

8.9 - Continued

```
                    RID ='INSTALLATION CASE 1, VALIDATION CASE 1 /

                    PID

                    UID
P 2  199UPPEBOUNUNIFNONEN  1INPCENTR 2
P 2  199   1   1   1   1N  1  1   1R 2C 2  1
P 2  199LOWEBOUNUNIFNONEN  1INPCENTR 2
P 2  199   2   1   1   1N  1  1   1R 2C 2  2
P 2  199UPPEBOUNUNIFNONEN  1INPCENTR 4
P 2  199   1   1   1   1N  1  1   1R 4C 2  3
P 2  199LOWEBOUNUNIFNONEN  1INPCENTR 4
P 2  199   2   1   1   1N  1  1   1R 4C 2  4
P 2  199UPPEBOUNUNIFNONEN  1INPCENTR 2
P 2  199   1   1   1   1N  1  1   1R 2C 4  5
P 2  199LOWEBOUNUNIFNONEN  1INPCENTR 2
P 2  199   2   1   1   1N  1  1   1R 2C 4  6
P 2  199UPPEBOUNUNIFNONEN  1INPCENTR 4
P 2  199   1   1   1   1N  1  1   1R 4C 4  7
P 2  199LOWEBOUNUNIFNONEN  1INPCENTR 4
P 2  199   2   1   1   1N  1  1   1R 4C 4  8
```

8.9 - Continued

RID = INSTALLATION CASE 1, VALIDATION CASE 1 /

PID

UID

SURFACE FLOW PROPERTIES AT PANEL CENTER CONTROL POINTS CASE NUMBER : 2 ID : ALPHA-VARIATION-SF

SOLUTION NO : 2 NETWORK NO : 1,ID : UPPER-WING ,IMAGE :INPUT

PRESSURE COMP UNIF VELOCITY COMPUTATON BOUN VELOCITY CORRECTION NONE

PDP PARAMETER NAME LIST IN ORDER OF DATA STORAGE

| | | | | | | |
|---|---|---|---|---|---|---|
| X | Y | Z | PWX | PWY | PWZ | MORE |
| WX | WY | WZ | WMAG | WN | PVX | MORE |
| PVY | PVZ | VX | VY | VZ | VMAG | MORE |
| PHI | PHIT | MLISEN | MLLINE | MLSECO | MLREDU | MORE |
| MLSLEN | CPISEN | CPLINE | CPSECO | CPREDU | CPSLEN | MORE |
| GMUX | GMUY | GMUZ | PSI | SINGS | SINGD | MORE |
| SPDMAX | SPDCRT | CPVAC | | | | |

8.9 - Continued

```
                    RID  = INSTALLATION CASE 1, VALIDATION CASE 1 /

                    PID

                    UID
P 2  299UPPEBOUNUNIFNONEN  1INPCENTR 2
P 2  299   1   1   1   1N  1  1   1R 2C 2  9
P 2  299LOWEBOUNUNIFNONEN  1INPCENTR 2
P 2  299   2   1   1   1N  1  1   1R 2C 2 10
P 2  299UPPEBOUNUNIFNONEN  1INPCENTR 4
P 2  299   1   1   1   1N  1  1   1R 4C 2 11
P 2  299LOWEBOUNUNIFNONEN  1INPCENTR 4
P 2  299   2   1   1   1N  1  1   1R 4C 2 12
P 2  299UPPEBOUNUNIFNONEN  1INPCENTR 2
P 2  299   1   1   1   1N  1  1   1R 2C 4 13
P 2  299LOWEBOUNUNIFNONEN  1INPCENTR 2
P 2  299   2   1   1   1N  1  1   1R 2C 4 14
P 2  299UPPEBOUNUNIFNONEN  1INPCENTR 4
P 2  299   1   1   1   1N  1  1   1R 4C 4 15
P 2  299LOWEBOUNUNIFNONEN  1INPCENTR 4
P 2  299   2   1   1   1N  1  1   1R 4C 4 16
```

8.9 - Continued

RID = INSTALLATION CASE 1, VALIDATION CASE 1 /

PID

UID

SURFACE FLOW PROPERTIES AT PANEL CENTER CONTROL POINTS CASE NUMBER : 2 ID : ALPHA-VARIATION-SF

SOLUTION NO : 3 NETWORK NO : 1,ID : UPPER-WING ,IMAGE :INPUT

PRESSURE COMP UNIF VELOCITY COMPUTATON BOUN VELOCITY CORRECTION NONE

PDP PARAMETER NAME LIST IN ORDER OF DATA STORAGE

| | | | | | | |
|---|---|---|---|---|---|---|
| X | Y | Z | PWX | PWY | PWZ | MORE |
| WX | WY | WZ | WMAG | WN | PVX | MORE |
| PVY | PVZ | VX | VY | VZ | VMAG | MORE |
| PHI | PHIT | MLISEN | MLLINE | MLSECO | MLREDU | MORE |
| MLSLEN | CPISEN | CPLINE | CPSECO | CPREDU | CPSLEN | MORE |
| GMUX | GMUY | GMUZ | PSI | SINGS | SINGD | MORE |
| SPDMAX | SPDCRT | CPVAC | | | | |

8.9 - Continued

```
                    RID  = INSTALLATION CASE 1, VALIDATION CASE 1 /

                    PID

                    UID
P 2  399UPPEBOUNUNIFNONEN  1INPCENTR 2
P 2  399   1   1   1   1N  1  1   1R 2C 2 17
P 2  399LOWEBOUNUNIFNONEN  1INPCENTR 2
P 2  399   2   1   1   1N  1  1   1R 2C 2 18
P 2  399UPPEBOUNUNIFNONEN  1INPCENTR 4
P 2  399   1   1   1   1N  1  1   1R 4C 2 19
P 2  399LOWEBOUNUNIFNONEN  1INPCENTR 4
P 2  399   2   1   1   1N  1  1   1R 4C 2 20
P 2  399UPPEBOUNUNIFNONEN  1INPCENTR 2
P 2  399   1   1   1   1N  1  1   1R 2C 4 21
P 2  399LOWEBOUNUNIFNONEN  1INPCENTR 2
P 2  399   2   1   1   1N  1  1   1R 2C 4 22
P 2  399UPPEBOUNUNIFNONEN  1INPCENTR 4
P 2  399   1   1   1   1N  1  1   1R 4C 4 23
P 2  399LOWEBOUNUNIFNONEN  1INPCENTR 4
P 2  399   2   1   1   1N  1  1   1R 4C 4 24
```

8.9 - Continued

```
                    RID  = INSTALLATION CASE 1, VALIDATION CASE 1 /

                    PID

                    UID

                      PPP SELECTION OPTIONS FOR CONFIGURATION DATA FROM CDP ARE
                      --------------------------------------------------------

                      NUMBER OF CASES     =   0
                      NUMBER OF SOLUTIONS =   0
                      NUMBER OF NETWORKS  =   1
                            0-USE DEFAULT VALUE FROM CDP
                          NOT 0-PPP SELECTION QUANTITY

          (CONFIGURATION DATA PLOT FILE FORMAT - TAPE 11)

RECORD
SET(S)/
SUBSET(S)
--------
  1     (6F10.5)          (DATA FORMAT)
  2     CDP PLOT TITLES CONSISTING OF 4 LINES OF INFORMATION
  2-1   $CONFIG DATA FROM CDP DATA BASE
  2-2   $( RUN ID )
  2-3   $( PROBLEM ID )
  2-4   $( USER ID )
  3     *RUN 40           (IDENTIFIES RUN NAME MAX LENGTH 40)
  4     $GLOBAL DATA
  4-1   DATE (YR/MO/DATE)
  4-2   AMACH,CALPHA,CBETA,NUMPOS,NNET,NSOL,NCASE
  4-3   POSNRM(I.E. NORMAL TO 1ST AND 2ND PLANES NORMAL TO POS)
  4-4   POSLOC(I.E. COORDS OF POINT COMMON TO 1ST AND 2ND PLANES)
  4-5   NETPPP,NETID(I.E. NETWORK INDEX AND ID, 2 NETWORKS/RECORD SUBSET)
  4-6   ALPHA(ANGLE OF ATTACK FOR EACH SOLUTION)
  4-7   BETA(ANGLE OF SIDESLIP FOR EACH SOLUTION)
  4-8   SOLUTION LIST AND ID, 2 SOLUTIONS/RECORD SUBSET
  4-9   CASE LIST AND ID, 2 CASES/RECORD SUBSET
  4-10  LIST OF REF DATA COEFF VALUES(SR,CR,BR)
  4-11  NUMAXS(NO OF AXIS SYSTEMS) AND AXISAR(LIST OF AXIS SYSTEMS, RCS-WAS-BAS-SAS)
  4-12  MOMLST(COORDS OF MOMENT REF VALUES FOR AXIS SYSTEMS, 3 BY NUMAXS)
  4-13  ELRLST(EULER ANGLES, BAS ONLY)
  5     CDP PARAMETER NAME LIST IN ORDER OF DATA STORAGE
  6     RUN NAME FOR CDP DATA(MAX LENGTH 40)
  7     CONFIG DATA FROM CDP IN ORDER OF PARAMETER NAME LIST
        (REPEAT 6 AND 7 ABOVE FOR ALL SELECTIONS)
  8     *EOF               (END OF CDP DATA)
```

8.9 - Continued

```
                RID  = INSTALLATION CASE 1, VALIDATION CASE 1 /

                PID

                UID

          RUN NAME IDENTIFICATION FOR CONFIG DATA FROM CDP
          ------------------------------------------------

          CDP        SEQ       VEL   PRESS VEL   CASE         PANEL ID
          ID         NO. SURF  COMP  COMP  CORR  NO.    IMAGE (ROW/COL)
          ---        --- ----- ----- ----- ----- -----  ----- ----------

           C  XXYYY  99  UPPE  BOUN  UNIF  NONE  C999   INP   PR99C99
                         LOWE  VIC   LOCA  SA1          1ST
                         UPLO        COMP  SA2          2ND
                         LOUP                           3RD
                         AVER

*PANELS   C    XXYYY
*COLUMN   C    XXCZZ
   SUMS
*NETWORK  C    XX
*CONFIG   C    CONWW
*ACCUM    C    ACCWW

          XX  - NETWORK NUMBER
          YYY - PANEL NUMBER
          ZZ  - COLUMN NUMBER
          WW  - CASE NUMBER
          CON - CONFIGURATION
          ACC - ACCUMULATION
          9   - INTEGER VALUE
```

8.9 - Continued

```
            RID  = INSTALLATION CASE 1. VALIDATION CASE 1 /

            PID

            UID


*************************************************************
*************************************************************
*****                                                   *****
*****     PRINT PLOT PROCESSOR                          *****
*************************************************************
*****     CASE NUMBER   =   1  ALPHA-VARIATION-FM       *****
*****                                                   *****
*************************************************************
*************************************************************
 OPTIONS SELECTED ARE
 --------------------

*****                                                   *****
NUMBER OF NETWORKS           =   1
NUMBER OF SOLUTIONS          =   3
PRESSURE RULES               =ISE  LIN  SEC  RED  SLE
VELOCITY COMPUTATION METHODS =B.C.
VELOCITY CORRECTION          =NONE
SURFACE TYPE                 =LOWE
PRESSURE COMPUTATION OPTION  =UNIFORM ONSET FLOW


COLUMN SUM IN RCS   3
COLUMN SUM IN WAS   3
COLUMN SUM IN BAS   3
COLUMN SUM IN SAS   3
PANEL SUM IN RCS    3
PANEL SUM IN WAS    3
PANEL SUM IN BAS    3
PANEL SUM IN SAS    3
NETWORK SUM         3
CONFIGURATION SUM   3
CASE ACCUMULATION   0
          (SELECTION OPTION FROM COP-DB)
               0 = NONE
               1 = PRINT ONLY
               2 = DB STORAGE ONLY
               3 = BOTH 1 AND 2
ACCUM. OPTIONS
     VEL. COMPUTAT. BOUNDARY
     VEL. CORRECTN. NONE
     PRESSURE RULE  ISENTROPIC
```

8.9 - Continued

```
LIST OF SELECTED SOLUTIONS
         1    2    3
```

```
      RID  = INSTALLATION CASE 1, VALIDATION CASE 1 /

      PID

      UID

--------------------------- G L O B A L   D A T A ---------------------------

 VALIDATION CASE 1, INSTALLATION CASE 1
    =   SIMPLE DELTA WING WITH THICKNESS
    RALPH L. CARMICAEL NASA/AMES - KEN SIDWELL /BOEING
DATE (YR/MO/DATE)              06/03/80
MACH NUMBER                        2.000
ANGLE OF ATTACK(DEGREES)           0.000
ANGLE OF SIDESLIP(DEGREES)         0.000
NUMBER OF PLANES OF SYMMETRY           2
     =0  NO PLANES OF SYMMETRY
     =1  ONE PLANE OF SYMMETRY
     =2  TWO PLANES OF SYMMETRY
NUMBER OF NETWORKS                     1
NUMBER OF SOLUTIONS                    3
NUMBER OF CASES                        2

POSITION NORMALS       0.00000   1.00000   0.00000   0.00000   0.00000   1.00000

POSITION LOCATIONS     0.00000   0.00000   0.00000

ALPHA VALUES(DEGREES)

   -.57295   0.00000    .57295

BETA VALUES(DEGREES)

   0.00000   0.00000   0.00000

REFERENCE DATA SR,CR AND BR  1.00     1.00     1.00

NUMBER OF AXIS SYSTEMS(NUMAXS)   2
LIST OF AXIS SYSTEMS  1  2

MOMENT REF COORDS(MOMLST) FOR ABOVE AXIS SYSTEMS(3 BY NUMAXS)
  0.00  0.00  0.00    0.00  0.00  0.00

EULER ANGLES(BAS ONLY)
  0.00  0.00  0.00
```

8.9 - Continued

```
                    RID  = INSTALLATION CASE 1, VALIDATION CASE 1 /

                    PID

                    UID
---------------------------- G L O B A L   D A T A (CONT.) ----------------------------



SEQ  NETWORK
NO   ID
   1 UPPER-WING



SEQ  SOLUTION              SEQ  SOLUTION
NO   ID                    NO   ID
   1 SOLN-1                  2 SOLN-2
   3 SOLN-3



SEQ  CASE                  SEQ  CASE
NO   ID                    NO   ID
   1 ALPHA-VARIATION-FM      2 ACCUMULATION-CASE-01
```

8.9 - Continued

RID = INSTALLATION CASE 1, VALIDATION CASE 1 /

PID

UID

CONFIGURATION FORCES AND MOMENTS - CASE NUMBER 1 ALPHA-VARIATION-FM

NUMBER OF NETWORKS SELECTED 1

SURFACE SELECTED LOWE

VELOCITY COMPUTATION OPTIONS BOUN

VELOCITY CORRECTION OPTIONS NONE

PRESSURE RULES SELECTED ISE LIN SEC RED SLE

AXES NAME(S) SELECTED RCS WAS

NUMBER OF SOLUTIONS SELECTED 3

SOLUTION NUMBERS

1 2 3

COP PARAMETER NAME LIST IN ORDER OF DATA STORAGE

| SOLN | UNIF | ALPHA | BETA | | | |
|---|---|---|---|---|---|---|
| FXISERC | FYISERC | FZISERC | MXISERC | MYISERC | MZISERC | MORE |
| FXLINRC | FYLINRC | FZLINRC | MXLINRC | MYLINRC | MZLINRC | MORE |
| FXSECRC | FYSECRC | FZSECRC | MXSECRC | MYSECRC | MZSECRC | MORE |
| FXREDRC | FYREDRC | FZREDRC | MXREDRC | MYREDRC | MZREDRC | MORE |
| FXSLERC | FYSLERC | FZSLERC | MXSLERC | MYSLERC | MZSLERC | MORE |
| FXISEWA | FYISEWA | FZISEWA | MXISEWA | MYISEWA | MZISEWA | MORE |
| FXLINWA | FYLINWA | FZLINWA | MXLINWA | MYLINWA | MZLINWA | MORE |
| FXSECWA | FYSECWA | FZSECWA | MXSECWA | MYSECWA | MZSECWA | MORE |
| FXREDWA | FYREDWA | FZREDWA | MXREDWA | MYREDWA | MZREDWA | MORE |
| FXSLEWA | FYSLEWA | FZSLEWA | MXSLEWA | MYSLEWA | MZSLEWA | |

8.9 - Continued

```
                    RID = INSTALLATION CASE 1, VALIDATION CASE 1 /

                    PID

                    UID
C 1  199LOWEBOUNUNIFNONEC  1INPPR 1C 1
C 1  299LOWEBOUNUNIFNONEC  1INPPR 2C 1
C 1C 199LOWEBOUNUNIFNONEC  1INP
C 1  199LOWEBOUNUNIFNONEC  1INPPR 1C 2
C 1  299LOWEBOUNUNIFNONEC  1INPPR 2C 2
C 1C 299LOWEBOUNUNIFNONEC  1INP
C 1   99LOWEBOUNUNIFNONEC  1INP
CCON 199LOWEBOUNUNIFNONEC  1

CDP PARAMETER NAME LIST IN ORDER OF DATA STORAGE
------------------------------------------------
     SOLN      UNIF      ALPHA      BETA                                  MORE
  FXISEWA   FYISEWA   FZISEWA   MXISEWA   MYISEWA   MZISEWA              MORE
  FXISEWA   FYISEWA   FZISEWA   MXISEWA   MYISEWA   MZISEWA
CACC 199LOWEBOUNUNIFNONEC  1
```

8.9 - Continued

```
**************************************************
*                                                *
*   PROGRAM PPP.    VERSION 1.0       IS FINISHED. *
*   DATE OF RUN IS  06/05/80                       *
*   TIME OF RUN IS  22.07.04                       *
*                                                *
**************************************************

    CP SECONDS USED BY PPP        =        .9370
```

8.9 - Continued

(contents of logical unit 9)

```
NETWORK GEOMETRY FROM DQG DATA BASE
 VALIDATION CASE 1, INSTALLATION CASE 1 /
    =   SIMPLE DELTA WING WITH THICKNESS
    RALPH L. CARMICHAEL NASA/AMES - KEN SIDWELL /BOEING
*START
$GLOBAL DATA
DATE  06/03/80
   2.00000   0.00000   0.00000    2    1
   0.00000   1.00000   0.00000   0.00000   0.00000   1.00000
   0.00000   0.00000   0.00000
   1 UPPER-WING
D  1 3 3UPPER-WING
   1          1    1    1      0.000000      0.000000      0.000000
   2          2    1    1       .500000      0.000000       .025000
   3          3    1    1      1.000000      0.000000      0.000000
   4          1    2    1       .500000       .500000      0.000000
   5          2    2    1       .750000       .500000       .012500
   6          3    2    1      1.000000       .500000      0.000000
   7          1    3    1      1.000000      1.000000      0.000000
   8          2    3    1      1.000000      1.000000      0.000000
   9          3    3    1      1.000000      1.000000      0.000000
*END
```

8.9 - Continued

(contents of logical unit 10)

```
(6F10.5)
$POINT DATA FROM POP DATA BASE
$ VALIDATION CASE 1, INSTALLATION CASE 1 /
$     =   SIMPLE DELTA WING WITH THICKNESS
$     RALPH L. CARMICHAEL NASA/AMES - KEN SIDWELL /BOEING
*RUN 40
$GLOBAL DATA
DATE  06/03/80
   2.00000   0.00000   0.00000    2    1    3    2
   0.00000   1.00000   0.00000   0.00000   0.00000   1.00000
   0.00000   0.00000   0.00000
   1 UPPER-WING
   -.57295   0.00000    .57295
   0.00000   0.00000   0.00000
   1 SOLN-1                              2 SOLN-2
   3 SOLN-3
   1 ZERO-ALPHA                          2 ALPHA-VARIATION-SF
     X          Y          Z         PWX        PWY        PWZ                MORE
    WX         WY         WZ        WMAG        WN        PVX                 MORE
   PVY        PVZ         VX          VY         VZ       VMAG                MORE
   PHI       PHIT     MLISEN     MLLINE     MLSECO     MLREDU                 MORE
MLSLEN     CPISEN     CPLINE     CPSECO     CPREDU     CPSLEN                 MORE
  GMUX       GMUY       GMUZ        PSI      SINGS      SINGD                 MORE
SPDMAX     SPDCRT      CPVAC
P 2  199UPPEBOUNUNIFNONEN  1INPCENTR 2
P 2  199   1   1   1   1N  1  1   1R 2C 2  1
    .43750    .24975    .00939   0.00000   0.00000   0.00000
    .99995   0.00000   -.01000   1.00000    .05985   0.00000
   0.00000   0.00000    .99995   0.00000   -.01000   1.00000
   0.00000    .43738   2.00000   2.00000   2.00000   2.00000
   2.00000   0.00000   0.00000   0.00000   0.00000   0.00000
    .03952   -.02860   -.00450   0.00000    .05980    .01139
   1.50000    .61237   -.35714
P 2  199LOWEBOUNUNIFNONEN  1INPCENTR 2
P 2  199   2   1   1   1N  1  1   1R 2C 2  2
    .43750    .24975    .00939    .12761    .03162    .06475
   1.12756    .03162    .05475   1.12933    .00005   -.04254
    .03162    .06475    .95741    .03162    .05475    .95950
   -.01139    .42600   1.86084   1.89207   1.86084   1.86084
   1.85765    .08586    .08636    .08682    .07936    .08123
    .03952   -.02860   -.00450   0.00000    .05980    .01139
   1.50000    .61237   -.35714
P 2  199UPPEBOUNUNIFNONEN  1INPCENTR 4
P 2  199   1   1   1   1N  1  1   1R 4C 2  3
    .81263    .24975    .00937   0.00000   0.00000   0.00000
    .99995   0.00000   -.01000   1.00000   -.03995   0.00000
   0.00000   0.00000    .99995   0.00000   -.01000   1.00000
   0.00000    .81249   2.00000   2.00000   2.00000   2.00000
   2.00000   0.00000   0.00000   0.00000   0.00000   0.00000
   -.03426    .01095   -.00514   0.00000   -.04000    .01027
   1.50000    .61237   -.35714
```

8.9 - continued

```
P 2  199LOWEBOUNUNIFNONEN  1INPCENTR 4
P 2  199   2   1   1   1N  1  1   1R 4C 2  4
    .81263     .24975     .00937    -.09672    -.01095    -.03521
    .90323    -.01095    -.04521     .90443     .00005     .03224
   -.01095    -.03521    1.03219    -.01095    -.04521    1.03324
   -.01027     .80222    2.12471    2.08748    2.12471    2.12471
   2.12270    -.06313    -.06518    -.06333    -.06758    -.06652
   -.03426     .01095    -.00514    0.00000    -.04000     .01027
   1.50000     .61237    -.35714
P 2  199UPPEBOUNUNIFNONEN  1INPCENTR 2
P 2  199   1   1   1   1N  1  1   1R 2C 4  5
    .81238     .74975     .00313    0.00000    0.00000    0.00000
    .99995    0.00000    -.01000    1.00000     .05985    0.00000
   0.00000    0.00000     .99995    0.00000    -.01000    1.00000
   0.00000     .81230    2.00000    2.00000    2.00000    2.00000
   2.00000    0.00000    0.00000    0.00000    0.00000    0.00000
    .05163    -.05596    -.00495    0.00000     .05985     .00387
   1.50000     .61237    -.35714
P 2  199LOWEBOUNUNIFNONEN  1INPCENTR 2
P 2  199   2   1   1   1N  1  1   1R 2C 4  6
    .81238     .74975     .00313     .16392     .05898     .06524
   1.16387     .05898     .05525    1.16668    -.00000    -.05464
    .05898     .06524     .94531     .05898     .05525     .94876
   -.00387     .80844    1.82598    1.86325    1.82598    1.82598
   1.82081     .11024     .11058     .11209     .09986     .10292
    .05163    -.05596    -.00495    0.00000     .05985     .00387
   1.50000     .61237    -.35714
P 2  199UPPEBOUNUNIFNONEN  1INPCENTR 4
P 2  199   1   1   1   1N  1  1   1R 4C 4  7
    .93750     .74975     .00313    0.00000    0.00000    0.00000
    .99995    0.00000    -.01000    1.00000    -.03995    0.00000
   0.00000    0.00000     .99995    0.00000    -.01000    1.00000
   0.00000     .93742    2.00000    2.00000    2.00000    2.00000
   2.00000    0.00000    0.00000    0.00000    0.00000    0.00000
    .01034    -.02150     .00155    0.00000    -.03990     .00783
   1.50000     .61237    -.35714
P 2  199LOWEBOUNUNIFNONEN  1INPCENTR 4
P 2  199   2   1   1   1N  1  1   1R 4C 4  8
    .93750     .74975     .00313     .03706     .02150    -.04180
   1.03701     .02150    -.05180    1.03852    -.00005    -.01235
    .02150    -.04180     .98760     .02150    -.05180     .98919
   -.00783     .92959    1.96158    1.96932    1.96158    1.96158
   1.96133     .02197     .02387     .02207     .02150     .02165
    .01034    -.02150     .00155    0.00000    -.03990     .00783
   1.50000     .61237    -.35714
      X          Y          Z        PWX        PWY        PWZ              MORE
     WX         WY         WZ       WMAG         WN        PVX              MORE
    PVY        PVZ         VX         VY         VZ       VMAG              MORE
    PHI       PHIT     MLISEN     MLLINE     MLSECO     MLREDU              MORE
 MLSLEN     CPISEN     CPLINE     CPSECO     CPREDU     CPSLEN              MORE
   GMUX       GMUY       GMUZ        PSI      SINGS      SINGD              MORE
 SPDMAX     SPDCRT      CPVAC
```

8.9 - Continued

```
P 2  299UPPEBOUNUNIFNONEN  1INPCENTR 2
P 2  299   1   1   1   1N  1  1   1R 2C 2  9
    .43750    .24975    .00939   0.00000   0.00000   0.00000
   1.00000   0.00000   0.00000   1.00000    .04988   0.00000
   0.00000   0.00000   1.00000   0.00000   0.00000   1.00000
   0.00000    .43750   2.00000   2.00000   2.00000   2.00000
   2.00000   0.00000   0.00000   0.00000   0.00000   0.00000
    .03337   -.02412   -.00380   0.00000    .04983    .01016
   1.50000    .61237   -.35714
P 2  299LOWEBOUNUNIFNONEN  1INPCENTR 2
P 2  299   2   1   1   1N  1  1   1R 2C 2 10
    .43750    .24975    .00939    .10763    .02663    .05400
   1.10763    .02663    .05400   1.10927    .00005   -.03588
    .02663    .05400    .96412    .02663    .05400    .96600
   -.01016    .42734   1.88233   1.90975   1.88233   1.88233
   1.88011    .07143    .07176    .07199    .06684    .06813
    .03337   -.02412   -.00380   0.00000    .04983    .01016
   1.50000    .61237   -.35714
P 2  299UPPEBOUNUNIFNONEN  1INPCENTR 4
P 2  299   1   1   1   1N  1  1   1R 4C 2 11
    .81263    .24975    .00937   0.00000   0.00000   0.00000
   1.00000   0.00000   0.00000   1.00000   -.04994   0.00000
   0.00000   0.00000   1.00000   0.00000   0.00000   1.00000
   0.00000    .81263   2.00000   2.00000   2.00000   2.00000
   2.00000   0.00000   0.00000   0.00000   0.00000   0.00000
   -.03905    .01359   -.00586   0.00000   -.04999    .00706
   1.50000    .61237   -.35714
P 2  299LOWEBOUNUNIFNONEN  1INPCENTR 4
P 2  299   2   1   1   1N  1  1   1R 4C 2 12
    .81263    .24975    .00937   -.10957   -.01359   -.04457
    .89043   -.01359   -.04457    .89164    .00005    .03652
   -.01359   -.04457   1.03652   -.01359   -.04457   1.03757
   -.00706    .80557   2.14176   2.09844   2.14176   2.14176
   2.13922   -.07087   -.07305   -.07122   -.07656   -.07522
   -.03905    .01359   -.00586   0.00000   -.04999    .00706
   1.50000    .61237   -.35714
P 2  299UPPEBOUNUNIFNONEN  1INPCENTR 2
P 2  299   1   1   1   1N  1  1   1R 2C 4 13
    .81238    .74975    .00313   0.00000   0.00000   0.00000
   1.00000   0.00000   0.00000   1.00000    .04988   0.00000
   0.00000   0.00000   1.00000   0.00000   0.00000   1.00000
   0.00000    .81238   2.00000   2.00000   2.00000   2.00000
   2.00000   0.00000   0.00000   0.00000   0.00000   0.00000
    .04483   -.05039   -.00420   0.00000    .04988    .00345
   1.50000    .61237   -.35714
P 2  299LOWEBOUNUNIFNONEN  1INPCENTR 2
P 2  299   2   1   1   1N  1  1   1R 2C 4 14
    .81238    .74975    .00313    .14202    .05290    .05446
   1.14202    .05290    .05446   1.14454   -.00000   -.04734
    .05290    .05446    .95266    .05290    .05446    .95568
   -.00345    .80892   1.84835   1.88211   1.84835   1.84835
   1.84454    .09445    .09468    .09564    .08667    .08891
    .04483   -.05039   -.00420   0.00000    .04988    .00345
   1.50000    .61237   -.35714
```

```
P 2  299UPPEBOUNUNIFNONEN  1INPCENTR 4
P 2  299   1    1    1   1N  1  1    1R 4C 4 15
    .93750     .74975     .00313    0.00000    0.00000    0.00000
   1.00000    0.00000    0.00000    1.00000    -.04994    0.00000
   0.00000    0.00000    1.00000    0.00000    0.00000    1.00000
   0.00000     .93750    2.00000    2.00000    2.00000    2.00000
   2.00000    0.00000    0.00000    0.00000    0.00000    0.00000
    .00321    -.01638     .00048    0.00000    -.04989     .00654
   1.50000     .61237    -.35714
P 2  299LOWEBOUNUNIFNONEN  1INPCENTR 4
P 2  299   2    1    1   1N  1  1    1R 4C 4 16
    .93750     .74975     .00313     .01717     .01638    -.05081
   1.01717     .01638    -.05081    1.01857    -.00005    -.00572
    .01638    -.05081     .99428     .01638    -.05081     .99571
   -.00654     .93096    1.98464    1.98520    1.98464    1.98464
   1.98458     .00863     .01144     .00869     .00856     .00859
    .00321    -.01638     .00048    0.00000    -.04989     .00654
   1.50000     .61237    -.35714
     X           Y           Z         PWX        PWY        PWZ                MORE
    WX          WY          WZ        WMAG        WN         PVX                MORE
   PVY         PVZ          VX          VY         VZ        VMAG               MORE
   PHI        PHIT      MLISEN      MLLINE     MLSECO     MLREDU                MORE
MLSLEN      CPISEN      CPLINE      CPSECO     CPREDU     CPSLEN                MORE
  GMUX        GMUY        GMUZ         PSI       SINGS      SING0              MORE
SPDMAX      SPDCRT       CPVAC
P 2  399UPPEBOUNUNIFNONEN  1INPCENTR 2
P 2  399   1    1    1   1N  1  1    1R 2C 2 17
    .43750     .24975     .00939    0.00000    0.00000    0.00000
    .99995    0.00000     .01000    1.00000     .03990    0.00000
   0.00000    0.00000     .99995    0.00000     .01000    1.00000
   0.00000     .43757    2.00000    2.00000    2.00000    2.00000
   2.00000    0.00000    0.00000    0.00000    0.00000    0.00000
    .02721    -.01963    -.00310    0.00000     .03985     .00893
   1.50000     .61237    -.35714
P 2  399LOWEBOUNUNIFNONEN  1INPCENTR 2
P 2  399   2    1    1   1N  1  1    1R 2C 2 18
    .43750     .24975     .00939     .08765     .02163     .04325
   1.08760     .02163     .05325    1.08912     .00005    -.02922
    .02163     .04325     .97073     .02163     .05325     .97243
   -.00893     .42864    1.90390    1.92713    1.90390    1.90390
   1.90246     .05739     .05756     .05769     .05437     .05520
    .02721    -.01963    -.00310    0.00000     .03985     .00893
   1.50000     .61237    -.35714
P 2  399UPPEBOUNUNIFNONEN  1INPCENTR 4
P 2  399   1    1    1   1N  1  1    1R 4C 2 19
    .81263     .24975     .00937    0.00000    0.00000    0.00000
    .99995    0.00000     .01000    1.00000    -.05992    0.00000
   0.00000    0.00000     .99995    0.00000     .01000    1.00000
   0.00000     .81268    2.00000    2.00000    2.00000    2.00000
   2.00000    0.00000    0.00000    0.00000    0.00000    0.00000
   -.04383     .01623    -.00657    0.00000    -.05997     .00384
   1.50000     .61237    -.35714
```

8.9 - Continued

```
P 2  399LOWEBOUNUNIFNONEN  1INPCENTR 4
P 2  399   2   1   1   1N  1  1   1R 4C 2 20
    .81263    .24975    .00937   -.12242   -.01623   -.05393
    .87753   -.01623   -.04393    .87878    .00005    .04081
   -.01623   -.05393   1.04076   -.01623   -.04393   1.04181
   -.00384    .80883   2.15863   2.10893   2.15863   2.15863
   2.15552   -.07833   -.08053   -.07888   -.08537   -.08375
   -.04383    .01623   -.00657   0.00000   -.05997    .00384
   1.50000    .61237   -.35714
P 2  399UPPEBOUNUNIFNONEN  1INPCENTR 2
P 2  399   1   1   1   1N  1  1   1R 2C 4 21
    .81238    .74975    .00313   0.00000   0.00000   0.00000
    .99995   0.00000    .01000   1.00000    .03990   0.00000
   0.00000   0.00000    .99995   0.00000    .01000   1.00000
   0.00000    .81237   2.00000   2.00000   2.00000   2.00000
   2.00000   0.00000   0.00000   0.00000   0.00000   0.00000
    .03802   -.04481   -.00346   0.00000    .03990    .00304
   1.50000    .61237   -.35714
P 2  399LOWEBOUNUNIFNONEN  1INPCENTR 2
P 2  399   2   1   1   1N  1  1   1R 2C 4 22
    .81238    .74975    .00313    .12010    .04682    .04366
   1.12005    .04682    .05366   1.12231   -.00000   -.04003
    .04682    .04366    .95992    .04682    .05366    .96256
   -.00304    .80933   1.87090   1.90073   1.87090   1.87090
   1.86821    .07905    .07919    .07976    .07349    .07505
    .03802   -.04481   -.00346   0.00000    .03990    .00304
   1.50000    .61237   -.35714
P 2  399UPPEBOUNUNIFNONEN  1INPCENTR 4
P 2  399   1   1   1   1N  1  1   1R 4C 4 23
    .93750    .74975    .00313   0.00000   0.00000   0.00000
    .99995   0.00000    .01000   1.00000   -.05992   0.00000
   0.00000   0.00000    .99995   0.00000    .01000   1.00000
   0.00000    .93748   2.00000   2.00000   2.00000   2.00000
   2.00000   0.00000   0.00000   0.00000   0.00000   0.00000
   -.00393   -.01126   -.00059   0.00000   -.05987    .00525
   1.50000    .61237   -.35714
P 2  399LOWEBOUNUNIFNONEN  1INPCENTR 4
P 2  399   2   1   1   1N  1  1   1R 4C 4 24
    .93750    .74975    .00313   -.00273    .01126   -.05981
    .99722    .01126   -.04981    .99853   -.00005    .00091
    .01126   -.05981   1.00086    .01126   -.04981   1.00216
   -.00525    .93224   2.00780   2.00081   2.00780   2.00780
   2.00780   -.00431   -.00062   -.00433   -.00433   -.00433
   -.00393   -.01126   -.00059   0.00000   -.05987    .00525
   1.50000    .61237   -.35714
*EOF
```

8.9 - Continued

```
(6F10.5)
$CONFIGURATION DATA FROM CDP DATA BASE                    (contents of logical unit 11)
$ VALIDATION CASE 1, INSTALLATION CASE 1
$    =   SIMPLE DELTA WING WITH THICKNESS
$    RALPH L. CARMICAEL NASA/AMES - KEN SIDWELL /BOEING
*RUN 40.
$GLOBAL DATA
DATE  06/03/80
   2.00000   0.00000   0.00000    2    1    3    2
   0.00000   1.00000   0.00000   0.00000   0.00000   1.00000
   0.00000   0.00000   0.00000
   1 UPPER-WING
   -.57295   0.00000    .57295
   0.00000   0.00000   0.00000
   1 SOLN-1                          2 SOLN-2
   3 SOLN-3
   1 ALPHA-VARIATION-FM              2 ACCUMULATION-CASE-01
   1.00000   1.00000   1.00000
   2   1   2
  0.00  0.00  0.00  0.00  0.00  0.00
  0.00  0.00  0.00
      SOLN      UNIF      ALPHA      BETA                                    MORE
   FXISERC   FYISERC   FZISERC   MXISERC   MYISERC   MZISERC                 MORE
   FXLINRC   FYLINRC   FZLINRC   MXLINRC   MYLINRC   MZLINRC                 MORE
   FXSECRC   FYSECRC   FZSECRC   MXSECRC   MYSECRC   MZSECRC                 MORE
   FXREDRC   FYREDRC   FZREDRC   MXREDRC   MYREDRC   MZREDRC                 MORE
   FXSLERC   FYSLERC   FZSLERC   MXSLERC   MYSLERC   MZSLERC                 MORE
   FXISEWA   FYISEWA   FZISEWA   MXISEWA   MYISEWA   MZISEWA                 MORE
   FXLINWA   FYLINWA   FZLINWA   MXLINWA   MYLINWA   MZLINWA                 MORE
   FXSECWA   FYSECWA   FZSECWA   MXSECWA   MYSECWA   MZSECWA                 MORE
   FXREDWA   FYREDWA   FZREDWA   MXREDWA   MYREDWA   MZREDWA                 MORE
   FXSLEWA   FYSLEWA   FZSLEWA   MXSLEWA   MYSLEWA   MZSLEWA
C 1  199LOWEBOUNUNIFNONEC  1INPPR 1C 1
         1   1.00000   -.57295   0.00000
    .00060   -.00060   -.01198   -.00309    .00538   -.00042
    .00062   -.00062   -.01246   -.00318    .00564   -.00044
    .00061   -.00061   -.01215   -.00314    .00547   -.00043
    .00056   -.00056   -.01115   -.00287    .00502   -.00039
    .00068   -.00068   -.01353   -.00342    .00615   -.00048
    .00072   -.00060   -.01197   -.00309    .00538   -.00045
    .00075   -.00062   -.01246   -.00317    .00564   -.00047
    .00073   -.00061   -.01215   -.00313    .00547   -.00046
    .00067   -.00056   -.01115   -.00286    .00502   -.00042
    .00081   -.00068   -.01352   -.00341    .00615   -.00051
         2   1.00000   0.00000   0.00000
    .00052   -.00052   -.01035   -.00267    .00471   -.00037
    .00053   -.00053   -.01069   -.00273    .00489   -.00038
    .00052   -.00052   -.01047   -.00270    .00477   -.00037
    .00048   -.00048   -.00970   -.00250    .00441   -.00035
    .00057   -.00057   -.01149   -.00291    .00527   -.00041
    .00052   -.00052   -.01035   -.00267    .00471   -.00037
    .00053   -.00053   -.01069   -.00273    .00489   -.00038
    .00052   -.00052   -.01047   -.00270    .00477   -.00037
    .00048   -.00048   -.00970   -.00250    .00441   -.00035
    .00057   -.00057   -.01149   -.00291    .00527   -.00041
```

8.9 - Continued

```
         3   1.00000    .57295   0.00000
     .00043   -.00043   -.00861   -.00223    .00398   -.00031
     .00044   -.00044   -.00885   -.00227    .00410   -.00032
     .00043   -.00043   -.00870   -.00224    .00402   -.00031
     .00041   -.00041   -.00812   -.00210    .00375   -.00029
     .00047   -.00047   -.00943   -.00240    .00439   -.00034
     .00034   -.00043   -.00862   -.00223    .00398   -.00029
     .00035   -.00044   -.00885   -.00227    .00410   -.00030
     .00035   -.00043   -.00870   -.00225    .00402   -.00029
     .00032   -.00041   -.00812   -.00210    .00375   -.00027
     .00038   -.00047   -.00944   -.00241    .00439   -.00032
C 1  299LOWEBOUNUNIFNONEC  1INPPR 2C 1
         1   1.00000   -.57295   0.00000
     .00059    .00000    .01177    .00253   -.00942   -.00013
     .00060    .00000    .01194    .00256   -.00957   -.00013
     .00059    .00000    .01187    .00254   -.00949   -.00013
     .00064    .00000    .01272    .00272   -.01018   -.00014
     .00057    .00000    .01138    .00244   -.00914   -.00012
     .00047    .00000    .01178    .00253   -.00942   -.00010
     .00048    .00000    .01195    .00256   -.00957   -.00010
     .00047    .00000    .01187    .00255   -.00949   -.00010
     .00051    .00000    .01273    .00272   -.01018   -.00011
     .00046    .00000    .01139    .00244   -.00914   -.00010
         2   1.00000   0.00000   0.00000
     .00069    .00000    .01388    .00298   -.01112   -.00015
     .00071    .00000    .01412    .00302   -.01132   -.00015
     .00070    .00000    .01402    .00301   -.01123   -.00015
     .00076    .00000    .01518    .00324   -.01215   -.00016
     .00067    .00000    .01335    .00286   -.01073   -.00014
     .00069    .00000    .01388    .00298   -.01112   -.00015
     .00071    .00000    .01412    .00302   -.01132   -.00015
     .00070    .00000    .01402    .00301   -.01123   -.00015
     .00076    .00000    .01518    .00324   -.01215   -.00016
     .00067    .00000    .01335    .00286   -.01073   -.00014
         3   1.00000    .57295   0.00000
     .00080    .00000    .01604    .00344   -.01286   -.00017
     .00082    .00000    .01637    .00350   -.01314   -.00017
     .00081    .00000    .01626    .00348   -.01303   -.00017
     .00089    .00000    .01779    .00380   -.01425   -.00019
     .00077    .00000    .01534    .00328   -.01234   -.00016
     .00096    .00000    .01603    .00344   -.01286   -.00021
     .00098    .00000    .01636    .00350   -.01314   -.00021
     .00098    .00000    .01625    .00348   -.01303   -.00021
     .00107    .00000    .01778    .00380   -.01425   -.00023
     .00092    .00000    .01533    .00327   -.01234   -.00020
C 1C 199LOWEBOUNUNIFNONEC  1INP
         1   1.00000   -.57295   0.00000
     .00119   -.00060   -.00020   -.00057   -.00404   -.00055
     .00122   -.00062   -.00052   -.00062   -.00393   -.00057
     .00120   -.00061   -.00029   -.00059   -.00402   -.00056
     .00119   -.00056    .00157   -.00015   -.00516   -.00053
     .00125   -.00068   -.00215   -.00098   -.00299   -.00060
     .00119   -.00060   -.00019   -.00056   -.00404   -.00056
     .00123   -.00062   -.00051   -.00061   -.00393   -.00057
     .00120   -.00061   -.00027   -.00059   -.00402   -.00056
     .00118   -.00056    .00158   -.00014   -.00516   -.00053
     .00127   -.00068   -.00213   -.00097   -.00299   -.00061
```

8.9 - Continued

```
         2   1.00000   0.00000   0.00000
     .00121  -.00052    .00353    .00031  -.00641  -.00052
     .00124  -.00053    .00343    .00029  -.00644  -.00053
     .00122  -.00052    .00355    .00031  -.00646  -.00052
     .00124  -.00048    .00549    .00074  -.00774  -.00051
     .00124  -.00057    .00185   -.00005  -.00545  -.00055
     .00121  -.00052    .00353    .00031  -.00641  -.00052
     .00124  -.00053    .00343    .00029  -.00644  -.00053
     .00122  -.00052    .00355    .00031  -.00646  -.00052
     .00124  -.00048    .00549    .00074  -.00774  -.00051
     .00124  -.00057    .00185   -.00005  -.00545  -.00055
         3   1.00000    .57295   0.00000
     .00123  -.00043    .00742    .00121  -.00888  -.00048
     .00126  -.00044    .00753    .00123  -.00903  -.00049
     .00125  -.00043    .00756    .00124  -.00900  -.00049
     .00130  -.00041    .00967    .00170  -.01050  -.00048
     .00124  -.00047    .00591    .00087  -.00795  -.00050
     .00131  -.00043    .00741    .00121  -.00888  -.00049
     .00134  -.00044    .00751    .00122  -.00903  -.00051
     .00132  -.00043    .00755    .00124  -.00900  -.00050
     .00139  -.00041    .00966    .00170  -.01050  -.00050
     .00130  -.00047    .00589    .00087  -.00795  -.00051
C 1  199LOWEBOUNUNIFNONEC  1INPPR 1C 2
         1   1.00000   -.57295   0.00000
     .00033  -.00033   -.00658   -.00458   .00558  -.00051
     .00029  -.00029   -.00582   -.00406   .00498  -.00045
     .00036  -.00036   -.00724   -.00508   .00615  -.00056
     .00021  -.00021   -.00428   -.00292   .00369  -.00033
     .00033  -.00033   -.00663   -.00465   .00565  -.00052
     .00039  -.00033   -.00657   -.00457   .00558  -.00055
     .00035  -.00029   -.00582   -.00405   .00498  -.00049
     .00043  -.00036   -.00724   -.00508   .00615  -.00061
     .00026  -.00021   -.00428   -.00292   .00369  -.00036
     .00040  -.00033   -.00663   -.00465   .00565  -.00056
         2   1.00000   0.00000   0.00000
     .00029  -.00029   -.00577   -.00401   .00492  -.00045
     .00025  -.00025   -.00509   -.00354   .00436  -.00040
     .00031  -.00031   -.00626   -.00437   .00533  -.00048
     .00019  -.00019   -.00385   -.00263   .00333  -.00030
     .00029  -.00029   -.00573   -.00401   .00490  -.00045
     .00029  -.00029   -.00577   -.00401   .00492  -.00045
     .00025  -.00025   -.00509   -.00354   .00436  -.00040
     .00031  -.00031   -.00626   -.00437   .00533  -.00048
     .00019  -.00019   -.00385   -.00263   .00333  -.00030
     .00029  -.00029   -.00573   -.00401   .00490  -.00045
         3   1.00000    .57295   0.00000
     .00025  -.00025   -.00493   -.00341   .00421  -.00038
     .00022  -.00022   -.00434   -.00301   .00373  -.00034
     .00026  -.00026   -.00527   -.00367   .00450  -.00041
     .00017  -.00017   -.00336   -.00230   .00292  -.00026
     .00024  -.00024   -.00483   -.00337   .00414  -.00038
     .00020  -.00025   -.00493   -.00342   .00421  -.00035
     .00017  -.00022   -.00434   -.00301   .00373  -.00031
     .00021  -.00026   -.00527   -.00367   .00450  -.00037
     .00013  -.00017   -.00337   -.00230   .00292  -.00024
     .00019  -.00024   -.00483   -.00338   .00414  -.00034
```

8.9 - Continued

```
C 1  299LOWEBOUNUNIFNONEC  1INPPR 2C 2
         1   1.00000   -.57295   0.00000
     .00000   -.00000    .00002   -.00025    .00005    .00001
     .00002   -.00000    .00031   -.00007   -.00022    .00000
    -.00000   -.00000   -.00002   -.00028    .00010    .00001
     .00004   -.00000    .00072    .00021   -.00061   -.00001
     .00000   -.00000    .00009   -.00022   -.00001    .00001
     .00000   -.00000    .00002   -.00025    .00005    .00001
     .00001   -.00000    .00031   -.00007   -.00022    .00000
    -.00000   -.00000   -.00002   -.00028    .00010    .00001
     .00003   -.00000    .00072    .00021   -.00061   -.00001
     .00000   -.00000    .00009   -.00022   -.00001    .00001
         2   1.00000   0.00000   0.00000
     .00006   -.00000    .00113    .00055   -.00101   -.00003
     .00006   -.00000    .00118    .00058   -.00106   -.00003
     .00006   -.00000    .00113    .00055   -.00101   -.00003
     .00007   -.00000    .00149    .00079   -.00136   -.00004
     .00005   -.00000    .00097    .00044   -.00086   -.00002
     .00006   -.00000    .00113    .00055   -.00101   -.00003
     .00006   -.00000    .00118    .00058   -.00106   -.00003
     .00006   -.00000    .00113    .00055   -.00101   -.00003
     .00007   -.00000    .00149    .00079   -.00136   -.00004
     .00005   -.00000    .00097    .00044   -.00086   -.00002
         3   1.00000    .57295   0.00000
     .00011   -.00000    .00215    .00129   -.00200   -.00006
     .00010   -.00000    .00209    .00125   -.00193   -.00006
     .00011   -.00000    .00218    .00131   -.00202   -.00007
     .00012   -.00000    .00238    .00144   -.00221   -.00007
     .00009   -.00000    .00185    .00110   -.00171   -.00005
     .00013   -.00000    .00215    .00129   -.00200   -.00008
     .00013   -.00000    .00209    .00125   -.00193   -.00008
     .00013   -.00000    .00218    .00131   -.00202   -.00008
     .00014   -.00000    .00238    .00144   -.00221   -.00009
     .00011   -.00000    .00184    .00110   -.00171   -.00007
C 1C 299LOWEBOUNUNIFNONEC  1INP
         1   1.00000   -.57295   0.00000
     .00033   -.00033   -.00655   -.00483    .00564   -.00050
     .00031   -.00029   -.00552   -.00413    .00476   -.00045
     .00036   -.00036   -.00727   -.00537    .00625   -.00055
     .00025   -.00021   -.00356   -.00272    .00309   -.00034
     .00034   -.00033   -.00655   -.00487    .00564   -.00050
     .00040   -.00033   -.00655   -.00482    .00564   -.00054
     .00036   -.00029   -.00551   -.00412    .00476   -.00049
     .00043   -.00036   -.00726   -.00536    .00625   -.00060
     .00029   -.00021   -.00356   -.00271    .00309   -.00037
     .00040   -.00033   -.00654   -.00487    .00564   -.00055
         2   1.00000   0.00000   0.00000
     .00035   -.00029   -.00465   -.00345    .00391   -.00047
     .00031   -.00025   -.00391   -.00296    .00330   -.00042
     .00037   -.00031   -.00513   -.00382    .00432   -.00051
     .00027   -.00019   -.00236   -.00185    .00197   -.00034
     .00033   -.00029   -.00477   -.00357    .00404   -.00047
     .00035   -.00029   -.00465   -.00345    .00391   -.00047
     .00031   -.00025   -.00391   -.00296    .00330   -.00042
     .00037   -.00031   -.00513   -.00382    .00432   -.00051
     .00027   -.00019   -.00236   -.00185    .00197   -.00034
     .00033   -.00029   -.00477   -.00357    .00404   -.00047
```

8.9 - Continued

```
         3  1.00000    .57295   0.00000
    .00035  -.00025  -.00278  -.00212   .00222  -.00045
    .00032  -.00022  -.00225  -.00176   .00179  -.00040
    .00037  -.00026  -.00309  -.00236   .00248  -.00047
    .00029  -.00017  -.00099  -.00086   .00071  -.00033
    .00033  -.00024  -.00299  -.00227   .00243  -.00043
    .00033  -.00025  -.00278  -.00213   .00222  -.00042
    .00030  -.00022  -.00225  -.00176   .00179  -.00038
    .00034  -.00026  -.00309  -.00236   .00248  -.00045
    .00028  -.00017  -.00099  -.00087   .00071  -.00032
    .00030  -.00024  -.00299  -.00228   .00243  -.00041
C 1   99LOWEBOUNUNIFNONEC  1INP
         1  1.00000   -.57295   0.00000
    .00152  -.00093  -.00675  -.00539   .00160  -.00105
    .00153  -.00091  -.00604  -.00474   .00083  -.00102
    .00156  -.00097  -.00755  -.00596   .00222  -.00110
    .00144  -.00077  -.00199  -.00286  -.00207  -.00087
    .00158  -.00101  -.00869  -.00585   .00265  -.00110
    .00158  -.00093  -.00674  -.00538   .00160  -.00110
    .00159  -.00091  -.00602  -.00473   .00083  -.00106
    .00164  -.00097  -.00754  -.00595   .00222  -.00116
    .00146  -.00077  -.00198  -.00286  -.00207  -.00090
    .00167  -.00101  -.00868  -.00584   .00265  -.00116
         2  1.00000   0.00000  0.00000
    .00156  -.00081  -.00112  -.00314  -.00250  -.00099
    .00155  -.00079  -.00048  -.00267  -.00314  -.00096
    .00159  -.00084  -.00158  -.00351  -.00214  -.00104
    .00151  -.00068   .00313  -.00110  -.00577  -.00085
    .00158  -.00086  -.00291  -.00363  -.00141  -.00102
    .00156  -.00081  -.00112  -.00314  -.00250  -.00099
    .00155  -.00079  -.00048  -.00267  -.00314  -.00096
    .00159  -.00084  -.00158  -.00351  -.00214  -.00104
    .00151  -.00068   .00313  -.00110  -.00577  -.00085
    .00158  -.00086  -.00291  -.00363  -.00141  -.00102
         3  1.00000   .57295   0.00000
    .00159  -.00068   .00464  -.00091  -.00666  -.00093
    .00158  -.00066   .00528  -.00053  -.00724  -.00089
    .00162  -.00070   .00447  -.00112  -.00652  -.00096
    .00158  -.00057   .00869   .00084  -.00979  -.00082
    .00157  -.00071   .00292  -.00140  -.00551  -.00093
    .00163  -.00068   .00463  -.00092  -.00666  -.00092
    .00163  -.00066   .00526  -.00054  -.00724  -.00089
    .00166  -.00070   .00445  -.00113  -.00652  -.00095
    .00167  -.00057   .00867   .00083  -.00979  -.00082
    .00160  -.00071   .00291  -.00141  -.00551  -.00092
CCON 199LOWEBOUNUNIFNONEC  1
         1  1.00000   -.57295   0.00000
    .00303  0.00000  -.01351  0.00000   .00319  0.00000
    .00305  0.00000  -.01207  0.00000   .00165  0.00000
    .00312  0.00000  -.01510  0.00000   .00444  0.00000
    .00289  0.00000  -.00398  0.00000  -.00415  0.00000
    .00316  0.00000  -.01738  0.00000   .00531  0.00000
    .00317  0.00000  -.01348  0.00000   .00319  0.00000
    .00317  0.00000  -.01204  0.00000   .00165  0.00000
    .00327  0.00000  -.01507  0.00000   .00444  0.00000
    .00293  0.00000  -.00395  0.00000  -.00415  0.00000
    .00334  0.00000  -.01735  0.00000   .00531  0.00000
```

8.9 - Continued

```
         2   1.00000    0.00000    0.00000
     .00303   0.00000   -.01351    0.00000    .00319   0.00000
     .00305   0.00000   -.01207    0.00000    .00165   0.00000
     .00312   0.00000   -.01510    0.00000    .00444   0.00000
     .00289   0.00000   -.00398    0.00000   -.00415   0.00000
     .00316   0.00000   -.01738    0.00000    .00531   0.00000
     .00317   0.00000   -.01348    0.00000    .00319   0.00000
     .00317   0.00000   -.01204    0.00000    .00165   0.00000
     .00327   0.00000   -.01507    0.00000    .00444   0.00000
     .00293   0.00000   -.00395    0.00000   -.00415   0.00000
     .00334   0.00000   -.01735    0.00000    .00531   0.00000
         3   1.00000    .57295    0.00000
     .00303   0.00000   -.01351    0.00000    .00319   0.00000
     .00305   0.00000   -.01207    0.00000    .00165   0.00000
     .00312   0.00000   -.01510    0.00000    .00444   0.00000
     .00289   0.00000   -.00398    0.00000   -.00415   0.00000
     .00316   0.00000   -.01738    0.00000    .00531   0.00000
     .00317   0.00000   -.01348    0.00000    .00319   0.00000
     .00317   0.00000   -.01204    0.00000    .00165   0.00000
     .00327   0.00000   -.01507    0.00000    .00444   0.00000
     .00293   0.00000   -.00395    0.00000   -.00415   0.00000
     .00334   0.00000   -.01735    0.00000    .00531   0.00000
       SOLN      UNIF      ALPHA      BETA                          MORE
   FXISERC   FYISERC   FZISERC   MXISERC   MYISERC   MZISERC        MORE
   FXISEWA   FYISEWA   FZISEWA   MXISEWA   MYISEWA   MZISEWA
CACC 199LOWEBOUNUNIFNONEC  1
         1   1.00000   -.57295    0.00000
     .00303   0.00000   -.01351    0.00000    .00319   0.00000
     .00317   0.00000   -.01348    0.00000    .00319   0.00000
*EOF
```

8.9 - Concluded

```
MECCC
COMMENT.
COMMENT.       **     EXECUTE   DIP       **
COMMENT.
ATTACH,DIP/UN=PADJR1.
DIP.
RETURN,DIP.
COMMENT.
COMMENT.       **     EXECUTE   DQG       **
COMMENT.
ATTACH,DQG/UN=PADJR1.
DQG.
RETURN,DQG.
COMMENT.
COMMENT.       **     EXECUTE   MAG       **
COMMENT.
ATTACH,MAG/UN=PADJR1.
MAG.
RETURN,MAG.
COMMENT.
COMMENT.       **     EXECUTE   RMS       **
COMMENT.
ATTACH,RMS/UN=PADJR1.
RMS.
RETURN,RMS.
COMMENT.
COMMENT.       **     EXECUTE   RHS       **
COMMENT.
ATTACH,RHS/UN=PADJR1.
RHS.
RETURN,RHS.
COMMENT.
COMMENT.       **     EXECUTE   MDG       **
COMMENT.
ATTACH,MDG/UN=PADJR1.
MDG.
RETURN,MDG.
COMMENT.
COMMENT.  **          PURGE DATA BASES NO LONGER NEEDED      **
COMMENT.
PURGE,MAKV11/UN=PAPKB1.
RETURN,MAKV11.
EXIT,U.
PURGE,MAKV12/UN=PAPKB1.
RETURN,MAKV12.
EXIT,U.
PURGE,MAKV13/UN=PAPKB1.
RETURN,MAKV13.
EXIT,U.
PURGE,MAKV14/UN=PAPKB1.
RETURN,MAKV14.
EXIT,U.
PURGE,MAUV11/UN=PAPKB1.
RETURN,MAUV11.
EXIT,U.
PURGE,MAUV12/UN=PAPKB1.
RETURN,MAUV12.
EXIT,U.
PURGE,MAUV13/UN=PAPKB1.
RETURN,MAUV13.
```

**Figure 8.10 - List of MECCC file on Boeing system**

```
EXIT,U.
PURGE,MAUV14/UN=PAPKB1.
RETURN,MAUV14.
EXIT,U.
PURGE,MICV11/UN=PAPKB1.
RETURN,MICV11.
EXIT,U.
PURGE,MICV12/UN=PAPKB1.
RETURN,MICV12.
EXIT,U.
PURGE,MICV13/UN=PAPKB1.
RETURN,MICV13.
EXIT,U.
PURGE,MICV14/UN=PAPKB1.
RETURN,MICV14.
EXIT,U.
PURGE,RMSV11/UN=PAPKB1.
RETURN,RMSV11.
EXIT,U.
PURGE,RMSV12/UN=PAPKB1.
RETURN,RMSV12.
EXIT,U.
PURGE,RMSV13/UN=PAPKB1.
RETURN,RMSV13.
EXIT,U.
PURGE,RMSV14/UN=PAPKB1.
RETURN,RMSV14.
EXIT,U.
PURGE,DQGV11/UN=PAPKB1.
RETURN,DQGV11.
EXIT,U.
PURGE,DQGV12/UN=PAPKB1.
RETURN,DQGV12.
EXIT,U.
PURGE,DQGV13/UN=PAPKB1.
RETURN,DQGV13.
EXIT,U.
PURGE,DQGV14/UN=PAPKB1.
RETURN,DQGV14.
EXIT,U.
PURGE,RHSV11/UN=PAPKB1.
RETURN,RHSV11.
EXIT,U.
PURGE,RHSV12/UN=PAPKB1.
RETURN,RHSV12.
EXIT,U.
PURGE,RHSV13/UN=PAPKB1.
RETURN,RHSV13.
EXIT,U.
PURGE,RHSV14/UN=PAPKB1.
RETURN,RHSV14.
EXIT,U.
COMMENT.
COMMENT.        **      EXECUTE   PDF       **
COMMENT.
ATTACH,PDF/UN=PADJF1.
PDF.
RETURN,PDF.
COMMENT.
COMMENT.        **      EXECUTE   CDF       **
```

Figure 8.10 - Continued

```
COMMENT.
ATTACH,CDP/UN=PADJR1.
CDP.
RETURN,CDP.
PURGE,MDGV11/UN=PAPKB1.
RETURN,MDGV11.
EXIT,U.
PURGE,MDGV12/UN=PAPKB1.
RETURN,MDGV12.
EXIT,U.
PURGE,MDGV13/UN=PAPKB1.
RETURN,MDGV13.
EXIT,U.
PURGE,MDGV14/UN=PAPKB1.
RETURN,MDGV14.
EXIT,U.
PURGE,DIPV11/UN=PAPKB1.
RETURN,DIPV11.
EXIT,U.
PURGE,DIPV12/UN=PAPKB1.
RETURN,DIPV12.
EXIT,U.
PURGE,DIPV13/UN=PAPKB1.
RETURN,DIPV13.
EXIT,U.
PURGE,DIPV14/UN=PAPKB1.
RETURN,DIPV14.
EXIT,U.
PURGE,PDPV11/UN=PAPKB1.
RETURN,PDPV11.
EXIT,U.
PURGE,PDPV12/UN=PAPKB1.
RETURN,PDPV12.
EXIT,U.
PURGE,PDPV13/UN=PAPKB1.
RETURN,PDPV13.
EXIT,U.
PURGE,PDPV14/UN=PAPKB1.
RETURN,PDPV14.
EXIT,U.
PURGE,CDPV11/UN=PAPKB1.
RETURN,CDPV11.
EXIT,U.
PURGE,CDPV12/UN=PAPKB1.
RETURN,CDPV12.
EXIT,U.
PURGE,CDPV13/UN=PAPKB1.
RETURN,CDPV13.
EXIT,U.
PURGE,CDPV14/UN=PAPKB1.
RETURN,CDPV14.
EXIT,U.
PURGE,RHSV11/UN=PAPKB1.
RETURN,RHSV11.
EXIT,U.
PURGE,RHSV12/UN=PAPKB1.
RETURN,RHSV12.
EXIT,U.
PURGE,RHSV13/UN=PAPKB1.
RETURN,RHSV13.
```

**Figure 8.10 - Continued**

```
EXIT,U.
PURGE,RHSV14/UN=PAPKB1.
RETURN,RHSV14.
EXIT,U.
PURGE,DGGV11/UN=PAPKB1.
RETURN,DGGV11.
EXIT,U.
PURGE,DGGV12/UN=PAPKB1.
RETURN,DGGV12.
EXIT,U.
PURGE,DGGV13/UN=PAPKB1.
RETURN,DGGV13.
EXIT,U.
PURGE,DGGV14/UN=PAPKB1.
RETURN,DGGV14.
EXIT,U.
EXIT.
```

Figure 8.10 - Concluded

MEC CONTROL CARDS

```
COMMENT.
COMMENT.       **     EXECUTE   DIP        **
COMMENT.
ATTACH,DIP/UN=039458C.
DIP.
COMMENT.
COMMENT.       **     EXECUTE   DQG        **
COMMENT.
ATTACH,DQG/UN=039458C.
DQG.
COMMENT.
COMMENT.       **     EXECUTE   MAG        **
COMMENT.
ATTACH,MAG/UN=039458C.
MAG.
COMMENT.
COMMENT.       **     EXECUTE   RMS        **
COMMENT.
ATTACH,RMS/UN=039458C.
RMS.
COMMENT.
COMMENT.       **     EXECUTE   RHS        **
COMMENT.
ATTACH,RHS/UN=039458C.
RHS.
COMMENT.
COMMENT.       **     EXECUTE   MDG        **
COMMENT.
ATTACH,MDG/UN=039458C.
MDG.
COMMENT.
COMMENT.   **         PURGE DATA BASES NO LONGER NEEDED     **
COMMENT.
PURGE,MAKV11.
PURGE,MAKV12.
PURGE,MAKV13.
PURGE,MAKV14.
PURGE,MAUV11.
PURGE,MAUV12.
PURGE,MAUV13.
PURGE,MAUV14.
PURGE,MICV11.
PURGE,MICV12.
PURGE,MICV13.
PURGE,MICV14.
PURGE,RMSV11.
PURGE,RMSV12.
```

8.11 - List of MECCC file on Langley system

```
PURGE,RMSV13.
PURGE,RMSV14.
PURGE,DOGV11.
PURGE,DOGV12.
PURGE,DOGV13.
PURGE,DOGV14.
PURGE,RHSV11.
PURGE,RHSV12.
PURGE,RHSV13.
PURGE,RHSV14.
COMMENT.
COMMENT.       **    EXECUTE   PDP       **
COMMENT.
ATTACH,PDP/UN=039458C.
PDP.
COMMENT.
COMMENT.       **    EXECUTE   CDP       **
COMMENT.
ATTACH,CDP/UN=039458C.
CDP.
PURGE,MDGV11.
PURGE,MDGV12.
PURGE,MDGV13.
PURGE,MDGV14.
PURGE,DIPV11.
PURGE,DIPV12.
PURGE,DIPV13.
PURGE,DIPV14.
PURGE,PDPV11.
PURGE,PDPV12.
PURGE,PDPV13.
PURGE,PDPV14.
PURGE,CDPV11.
PURGE,CDPV12.
PURGE,CDPV13.
PURGE,CDPV14.
PURGE,RHSV11.
PURGE,RHSV12.
PURGE,RHSV13.
PURGE,RHSV14.
PURGE,DOGV11.
PURGE,DOGV12.
PURGE,DOGV13.
PURGE,DOGV14.
EXIT.
```

8.11 - Concluded

MEC CONTROL CARDS

```
.PROC,MECCC.
COMMENT.
COMMENT.       **     EXECUTE   DIP        **
COMMENT.
ATTACH,DIP,ID=PANAIR,SN=FAEBRP2.
REWIND,INPUT.
DIP,INPUT.
RETURN,DIP.
COMMENT.
COMMENT.       **     EXECUTE   DQG        **
COMMENT.
ATTACH,DQG,ID=PANAIR,SN=FAEBRP2.
DQG.
RETURN,DQG.
COMMENT.
COMMENT.       **     EXECUTE   MAG        **
COMMENT.
ATTACH,MAG,ID=PANAIR,SN=FAEBRP2.
MAG.
RETURN,MAG.
COMMENT.
COMMENT.       **     EXECUTE   RMS        **
COMMENT.
ATTACH,RMS,ID=PANAIR,SN=FAEBRP2.
RMS.
RETURN,RMS.
COMMENT.
COMMENT.       **     EXECUTE   RHS        **
COMMENT.
ATTACH,RHS,ID=PANAIR,SN=FAEBRP2.
RHS.
RETURN,RHS.
COMMENT.
COMMENT.       **     EXECUTE   MDG        **
COMMENT.
ATTACH,MDG,ID=PANAIR,SN=FAEBRP2.
MDG.
RETURN,MDG.
COMMENT.
COMMENT.   **         PURGE DATA BASES NO LONGER NEEDED     **
COMMENT.
PURGE,MAKV11,MAKV11,ID=FAELLE,SN=FAEBRP2,MR=0.
RETURN,MAKV11.
EXIT,U.
PURGE,MAKV12,MAKV12,ID=FAELLE,SN=FAEBRP2,MR=0.
RETURN,MAKV12.
EXIT,U.
PURGE,MAKV13,MAKV13,ID=FAELLE,SN=FAEBRP2,MR=0.
RETURN,MAKV13.
EXIT,U.
PURGE,MAKV14,MAKV14,ID=FAELLE,SN=FAEBRP2,MR=0.
RETURN,MAKV14.
EXIT,U.
PURGE,MAUV11,MAUV11,ID=FAELLE,SN=FAEBRP2,MR=0.
RETURN,MAUV11.
EXIT,U.
PURGE,MAUV12,MAUV12,ID=FAELLE,SN=FAEBRP2,MR=0.
RETURN,MAUV12.
EXIT,U.
```

Figure 8.12 - List of MECCC file on Ames system

```
PURGE,MAUV13,MAUV13,ID=FAELLE,SN=FAEBRP2,MR=0.
RETURN,MAUV13.
EXIT,U.
PURGE,MAUV14,MAUV14,ID=FAELLE,SN=FAEBRP2,MR=0.
RETURN,MAUV14.
EXIT,U.
PURGE,MICV11,MICV11,ID=FAELLE,SN=FAEBRP2,MR=0.
RETURN,MICV11.
EXIT,U.
PURGE,MICV12,MICV12,ID=FAELLE,SN=FAEBRP2,MR=0.
RETURN,MICV12.
EXIT,U.
PURGE,MICV13,MICV13,ID=FAELLE,SN=FAEBRP2,MR=0.
RETURN,MICV13.
EXIT,U.
PURGE,MICV14,MICV14,ID=FAELLE,SN=FAEBRP2,MR=0.
RETURN,MICV14.
EXIT,U.
PURGE,RMSV11,RMSV11,ID=FAELLE,SN=FAEBRP2,MR=0.
RETURN,RMSV11.
EXIT,U.
PURGE,RMSV12,RMSV12,ID=FAELLE,SN=FAEBRP2,MR=0.
RETURN,RMSV12.
EXIT,U.
PURGE,RMSV13,RMSV13,ID=FAELLE,SN=FAEBRP2,MR=0.
RETURN,RMSV13.
EXIT,U.
PURGE,RMSV14,RMSV14,ID=FAELLE,SN=FAEBRP2,MR=0.
RETURN,RMSV14.
EXIT,U.
PURGE,DQGV11,DQGV11,ID=FAELLE,SN=FAEBRP2,MR=0.
RETURN,DQGV11.
EXIT,U.
PURGE,DQGV12,DQGV12,ID=FAELLE,SN=FAEBRP2,MR=0.
RETURN,DQGV12.
EXIT,U.
PURGE,DQGV13,DQGV13,ID=FAELLE,SN=FAEBRP2,MR=0.
RETURN,DQGV13.
EXIT,U.
PURGE,DQGV14,DQGV14,ID=FAELLE,SN=FAEBRP2,MR=0.
RETURN,DQGV14.
EXIT,U.
PURGE,RHSV11,RHSV11,ID=FAELLE,SN=FAEBRP2,MR=0.
RETURN,RHSV11.
EXIT,U.
PURGE,RHSV12,RHSV12,ID=FAELLE,SN=FAEBRP2,MR=0.
RETURN,RHSV12.
EXIT,U.
PURGE,RHSV13,RHSV13,ID=FAELLE,SN=FAEBRP2,MR=0.
RETURN,RHSV13.
EXIT,U.
PURGE,RHSV14,RHSV14,ID=FAELLE,SN=FAEBRP2,MR=0.
RETURN,RHSV14.
EXIT,U.
COMMENT.
COMMENT.        **      EXECUTE   POP         **
COMMENT.
ATTACH,POP,ID=PANAIR,SN=FAEBPP2.
POP.
RETURN,POP.
COMMENT.
COMMENT.        **      EXECUTE   COP         **
COMMENT.
ATTACH,COP,ID=PANAIR,SN=FAEBRP2.
COP.
RETURN,COP.
```

Figure 8.12 - Continued

```
PURGE,MDGV11,MDGV11,ID=FAELLE,SN=FAEBRP2,MR=0.
RETURN,MDGV11.
EXIT,U.
PURGE,MDGV12,MDGV12,ID=FAELLE,SN=FAEBRP2,MR=0.
RETURN,MDGV12.
EXIT,U.
PURGE,MDGV13,MDGV13,ID=FAELLE,SN=FAEBRP2,MR=0.
RETURN,MDGV13.
EXIT,U.
PURGE,MDGV14,MDGV14,ID=FAELLE,SN=FAEBRP2,MR=0.
RETURN,MDGV14.
EXIT,U.
PURGE,DIPV11,DIPV11,ID=FAELLE,SN=FAEBRP2,MR=0.
RETURN,DIPV11.
EXIT,U.
PURGE,DIPV12,DIPV12,ID=FAELLE,SN=FAEBRP2,MR=0.
RETURN,DIPV12.
EXIT,U.
PURGE,DIPV13,DIPV13,ID=FAELLE,SN=FAEBRP2,MR=0.
RETURN,DIPV13.
EXIT,U.
PURGE,DIPV14,DIPV14,ID=FAELLE,SN=FAEBRP2,MR=0.
RETURN,DIPV14.
EXIT,U.
PURGE,PDPV11,PDPV11,ID=FAELLE,SN=FAEBRP2,MR=0.
RETURN,PDPV11.
EXIT,U.
PURGE,PDPV12,PDPV12,ID=FAELLE,SN=FAEBRP2,MR=0.
RETURN,PDPV12.
EXIT,U.
PURGE,PDPV13,PDPV13,ID=FAELLE,SN=FAEBRP2,MR=0.
RETURN,PDPV13.
EXIT,U.
PURGE,PDPV14,PDPV14,ID=FAELLE,SN=FAEBRP2,MR=0.
RETURN,PDPV14.
EXIT,U.
PURGE,CDPV11,CDPV11,ID=FAELLE,SN=FAEBRP2,MR=0.
RETURN,CDPV11.
EXIT,U.
PURGE,CDPV12,CDPV12,ID=FAELLE,SN=FAEBRP2,MR=0.
RETURN,CDPV12.
EXIT,U.
PURGE,CDPV13,CDPV13,ID=FAELLE,SN=FAEBRP2,MR=0.
RETURN,CDPV13.
EXIT,U.
PURGE,CDPV14,CDPV14,ID=FAELLE,SN=FAEBRP2,MR=0.
RETURN,CDPV14.
EXIT,U.
PURGE,RHSV11,RHSV11,ID=FAELLE,SN=FAEBRP2,MR=0.
RETURN,RHSV11.
EXIT,U.
PURGE,RHSV12,RHSV12,ID=FAELLE,SN=FAEBRP2,MR=0.
RETURN,RHSV12.
EXIT,U.
PURGE,RHSV13,RHSV13,ID=FAELLE,SN=FAEBRP2,MR=0.
RETURN,RHSV13.
EXIT,U.
PURGE,RHSV14,RHSV14,ID=FAELLE,SN=FAEBRP2,MR=0.
RETURN,RHSV14.
EXIT,U.
PURGE,DQGV11,DQGV11,ID=FAELLE,SN=FAEBRP2,MR=0.
RETURN,DQGV11.
EXIT,U.
PURGE,DQGV12,DQGV12,ID=FAELLE,SN=FAEBRP2,MR=0.
RETURN,DQGV12.
EXIT,U.
```

Figure 8.12 - Continued

```
PURGE,DQGV13,DQGV13,ID=FAELLE,SN=FAEBRP2,MR=0.
RETURN,DQGV13.
EXIT,U.
PURGE,DQGV14,DQGV14,ID=FAELLE,SN=FAEBRP2,MR=0.
RETURN,DQGV14.
EXIT,U.
EXIT.
REVERT.
```

Figure 8.12 - Concluded

```
.PROC,MECCC.
COMMENT.
COMMENT.        **      EXECUTE  DIP        **
COMMENT.
ATTACH,DIP,ID=PANAIR,SN=AFFDL.
DIP.
RETURN,DIP.
COMMENT.
COMMENT.        **      EXECUTE  DQG        **
COMMENT.
ATTACH,DQG,ID=PANAIR,SN=AFFDL.
DQG.
RETURN,DQG.
COMMENT.
COMMENT.        **      EXECUTE  MAG        **
COMMENT.
ATTACH,MAG,ID=PANAIR,SN=AFFDL.
MAG.
RETURN,MAG.
COMMENT.
COMMENT.        **      EXECUTE  RMS        **
COMMENT.
ATTACH,RMS,ID=PANAIR,SN=AFFDL.
RMS.
RETURN,RMS.
COMMENT.
COMMENT.        **      EXECUTE  RHS        **
COMMENT.
ATTACH,RHS,ID=PANAIR,SN=AFFDL.
RHS.
RETURN,RHS.
COMMENT.
COMMENT.        **      EXECUTE  MDG        **
COMMENT.
ATTACH,MDG,ID=PANAIR,SN=AFFDL.
MDG.
RETURN,MDG.
COMMENT.
COMMENT.    **          PURGE DATA BASES NO LONGER NEEDED      **
COMMENT.
PURGE,MAK1,MAK1,ID=DEJONG,SN=AFFDL,MR=0.
RETURN,MAK1.
EXIT,U.
PURGE,MAK2,MAK2,ID=DEJONG,SN=AFFDL,MR=0.
RETURN,MAK2.
EXIT,U.
PURGE,MAK3,MAK3,ID=DEJONG,SN=AFFDL,MR=0.
RETURN,MAK3.
EXIT,U.
PURGE,MAK4,MAK4,ID=DEJONG,SN=AFFDL,MR=0.
RETURN,MAK4.
EXIT,U.
PURGE,MAU1,MAU1,ID=DEJONG,SN=AFFDL,MR=0.
RETURN,MAU1.
EXIT,U.
PURGE,MAU2,MAU2,ID=DEJONG,SN=AFFDL,MR=0.
RETURN,MAU2.
EXIT,U.
PURGE,MAU3,MAU3,ID=DEJONG,SN=AFFDL,MR=0.
RETURN,MAU3.
EXIT,U.
PURGE,MAU4,MAU4,ID=DEJONG,SN=AFFDL,MR=0.
```

**Figure 8.13 - List of MECCC file on Wright system**

```
RETURN,MAU4.
EXIT,U.
PURGE,MIC1,MIC1,ID=DEJONG,SN=AFFDL,MR=0.
RETURN,MIC1.
EXIT,U.
PURGE,MIC2,MIC2,ID=DEJONG,SN=AFFDL,MR=0.
RETURN,MIC2.
EXIT,U.
PURGE,MIC3,MIC3,ID=DEJONG,SN=AFFDL,MR=0.
RETURN,MIC3.
EXIT,U.
PURGE,MIC4,MIC4,ID=DEJONG,SN=AFFDL,MR=0.
RETURN,MIC4.
EXIT,U.
PURGE,RMS1,RMS1,ID=DEJONG,SN=AFFDL,MR=0.
RETURN,RMS1.
EXIT,U.
PURGE,RMS2,RMS2,ID=DEJONG,SN=AFFDL,MR=0.
RETURN,RMS2.
EXIT,U.
PURGE,RMS3,RMS3,ID=DEJONG,SN=AFFDL,MR=0.
RETURN,RMS3.
EXIT,U.
PURGE,RMS4,RMS4,ID=DEJONG,SN=AFFDL,MR=0.
RETURN,RMS4.
EXIT,U.
PURGE,DQG1,DQG1,ID=DEJONG,SN=AFFDL,MR=0.
RETURN,DQG1.
EXIT,U.
PURGE,DQG2,DQG2,ID=DEJONG,SN=AFFDL,MR=0.
RETURN,DQG2.
EXIT,U.
PURGE,DQG3,DQG3,ID=DEJONG,SN=AFFDL,MR=0.
RETURN,DQG3.
EXIT,U.
PURGE,DQG4,DQG4,ID=DEJONG,SN=AFFDL,MR=0.
RETURN,DQG4.
EXIT,U.
PURGE,RHS1,RHS1,ID=DEJONG,SN=AFFDL,MR=0.
RETURN,RHS1.
EXIT,U.
PURGE,RHS2,RHS2,ID=DEJONG,SN=AFFDL,MR=0.
RETURN,RHS2.
EXIT,U.
PURGE,RHS3,RHS3,ID=DEJONG,SN=AFFDL,MR=0.
RETURN,RHS3.
EXIT,U.
PURGE,RHS4,RHS4,ID=DEJONG,SN=AFFDL,MR=0.
RETURN,RHS4.
EXIT,U.
COMMENT.
COMMENT.        **      EXECUTE   PDP         **
COMMENT.
ATTACH,PDP,ID=PANAIR,SN=AFFDL.
PDP.
RETURN,PDP.
COMMENT.
COMMENT.        **      EXECUTE   CDP         **
COMMENT.
ATTACH,CDP,ID=PANAIR,SN=AFFDL.
CDP.
RETURN,CDP.
PURGE,MDG1,MDG1,ID=DEJONG,SN=AFFDL,MR=0.
RETURN,MDG1.
EXIT,U.
PURGE,MDG2,MDG2,ID=DEJONG,SN=AFFDL,MR=0.
```

Figure 8.13 - Continued

```
RETURN,MDG2.
EXIT,U.
PURGE,MDG3,MDG3,ID=DEJONG,SN=AFFDL,MR=0.
RETURN,MDG3.
EXIT,U.
PURGE,MDG4,MDG4,ID=DEJONG,SN=AFFDL,MR=0.
RETURN,MDG4.
EXIT,U.
PURGE,DIP1,DIP1,ID=DEJONG,SN=AFFDL,MR=0.
RETURN,DIP1.
EXIT,U.
PURGE,DIP2,DIP2,ID=DEJONG,SN=AFFDL,MR=0.
RETURN,DIP2.
EXIT,U.
PURGE,DIP3,DIP3,ID=DEJONG,SN=AFFDL,MR=0.
RETURN,DIP3.
EXIT,U.
PURGE,DIP4,DIP4,ID=DEJONG,SN=AFFDL,MR=0.
RETURN,DIP4.
EXIT,U.
PURGE,PDP1,PDP1,ID=DEJONG,SN=AFFDL,MR=0.
RETURN,PDP1.
EXIT,U.
PURGE,PDP2,PDP2,ID=DEJONG,SN=AFFDL,MR=0.
RETURN,PDP2.
EXIT,U.
PURGE,PDP3,PDP3,ID=DEJONG,SN=AFFDL,MR=0.
RETURN,PDP3.
EXIT,U.
PURGE,PDP4,PDP4,ID=DEJONG,SN=AFFDL,MR=0.
RETURN,PDP4.
EXIT,U.
PURGE,CDP1,CDP1,ID=DEJONG,SN=AFFDL,MR=0.
RETURN,CDP1.
EXIT,U.
PURGE,CDP2,CDP2,ID=DEJONG,SN=AFFDL,MR=0.
RETURN,CDP2.
EXIT,U.
PURGE,CDP3,CDP3,ID=DEJONG,SN=AFFDL,MR=0.
RETURN,CDP3.
EXIT,U.
PURGE,CDP4,CDP4,ID=DEJONG,SN=AFFDL,MR=0.
RETURN,CDP4.
EXIT,U.
PURGE,RHS1,RHS1,ID=DEJONG,SN=AFFDL,MR=0.
RETURN,RHS1.
EXIT,U.
PURGE,RHS2,RHS2,ID=DEJONG,SN=AFFDL,MR=0.
RETURN,RHS2.
EXIT,U.
PURGE,RHS3,RHS3,ID=DEJONG,SN=AFFDL,MR=0.
RETURN,RHS3.
EXIT,U.
PURGE,RHS4,RHS4,ID=DEJONG,SN=AFFDL,MR=0.
RETURN,RHS4.
EXIT,U.
PURGE,DQG1,DQG1,ID=DEJONG,SN=AFFDL,MR=0.
RETURN,DQG1.
EXIT,U.
PURGE,DQG2,DQG2,ID=DEJONG,SN=AFFDL,MR=0.
RETURN,DQG2.
EXIT,U.
PURGE,DQG3,DQG3,ID=DEJONG,SN=AFFDL,MR=0.
RETURN,DQG3.
EXIT,U.
PURGE,DQG4,DQG4,ID=DEJONG,SN=AFFDL,MR=0.
```

**Figure 8.13 - Continued**

```
RETURN,DQG4.
EXIT,U.
EXIT.
REVERT.
```

Figure 8.13 - Concluded

## 9.0 PAN AIR Engineering Glossary

This glossary defines the most commonly used engineering terms in the PAN AIR Theory and User's Documents. In general, all specialized terms (that is, terms whose meaning in the context of PAN AIR is different from their meaning in common usage) are included, as are standard engineering terms which are used in the PAN AIR engineering documents. Terms which relate to the computing aspects of PAN AIR are defined in a separate glossary, the PAN AIR software glossary.

The format of the glossary is the following: Each term is followed by a list of principal references and a definition. The references give the section number where the item is discussed, preceded by a T for Theory Document, a U for User's Document, and an S for Summary Document.

| ITEM | DEFINITION | REFERENCES |
|---|---|---|
| Abutment | A curve where two or more network edges (exactly or approximately) meet. | T-5.3, U-B.3.5 |
| Abutment, empty space | An abutment involving only one network edge, which is thus a free edge. | T-F.2 |
| Abutment intersection | A point where several abutments meet. | T-5.3, T-F.5 |
| Abutments, overlapping | Two distinct user-defined abutments which involve the same portion of some network edge. | Program printout only |
| Abutments, pairwise | Abutments involving pairs of network edges. They are generated by the program whenever the distance between network edges is less than the tolerance distance. | T-F.2 |
| Abutment parameterization | The assignment of a real number between zero and one to each panel corner or panel edge midpoint in an abutment. Zero is assigned to the starting point, one to the end point. | T-F.6 |
| Abutment, program generated | An abutment generated by the program rather than defined by the user, involving any number of network edges, computed by analyzing pairwise abutments. | T-F.2 |
| Abutment search, automatic | The process by which the program determines the set of all pairwise abutments. | T-F.3 |
| Abutments, user-defined | Any abutment which the program user identifies. | T-F.2 |
| Angle of attack, $\alpha$ | The angle of coordinate rotation about the y-axis; this appears in the coordinate transformation (rotation) matrices. | T-5.2, U-B.2.2 |
| Angle of sideslip, $\beta$ | The angle of coordinate rotation about the modified z-axis; this appears in coordinate transformation (rotation) matrices.<br><br>Note: The effect of the orientation of the flow due to the specification of an angle of attack $\alpha$ and an angle of sideslip $\beta$ corresponds to effect of rotating the configuration through the sideslip angle $\beta$, followed by a rotation through the angle of attack $\alpha$. | T-5.2, U-B.2.2 |

| ITEM | DEFINITION | REFERENCES |
|---|---|---|
| Area, reference | A user-defined scaling factor for the force and moment coefficient computation. | T-0.1, U-B.4.3 |
| Axis system | A coordinate system in which the force and moment coefficients are expressed. | U-2.1.7; U-B.2.1 |
| Axis system, body | An arbitrary user-defined coordinate system specified by means of Euler angles. | U-2.1.7, U-B.2.1 |
| Axis system, reference | The reference coordinate system (that system in which user defines the configuration geometry). | U-2.1.7, U-B.2.1 |
| Axis system, stability | The coordinate system conventionally used by stability and control engineers. | U-2.1.7, U-B.2.1 |
| Axis system, wind | The coordinate system whose x-axis is aligned with uniform onset flow. | U-2.1.7, U-B.2.1 |

| ITEM | DEFINITION | REFERENCES |
|---|---|---|
| Basis function | A function (of surface coordinates) which expresses the distribution due to a unit value of a single singularity parameter. | T-3.3, T-4.2.1 |
| Boundary condition | A linear equation imposed at points on the configuration. This equation specifies some combination of the velocity potential and its derivatives. | T-2.5, T-3.2, T-3.3, T-4.2, T-5.4, T-H |
| Boundary surface | A surface, defined by the user, on which boundary conditions are imposed. | U-A.3 |
| Boundary condition, aerodynamic | The specific form of boundary conditions for the aerodynamic problem in PAN AIR. | T-K.3 |
| Boundary condition classes | The result of grouping the boundary conditions into five separate categories. | U-B.3.1 |
| Boundary condition, closure | An equation specifying the total normal mass flux passing through a surface. | U-B.3.5, T-5.4, T-5.7.1, T-K.4 |
| Boundary condition coefficient, average, $( )_A$ | The average of upper and lower coefficients. | T-5.4, U-B.3.1 |
| Boundary condition coefficient, difference, $( )_D$ | The difference of upper and lower coefficients. | T-5.4, U-B.3.1 |
| Boundary condition coefficients, upper (lower), $( )_U$, $( )_L$ | Coefficients in the boundary condition equations corresponding to the upper (lower) side of the configuration. | T-5.4, U-B.3.1 |
| Boundary condition, doublet (or edge) matching | A boundary condition specifying continuity of doublet strength across network edges. | T-5.3, T-5.7.1, T-F |
| Boundary condition hierarchy | An ordering of all admissible boundary conditions defined by the program. When two user-input boundary conditions are supplied and only one needs to be imposed, the program imposes that boundary condition which is higher on the hierarchy. | T-H.2.5 |

| ITEM | DEFINITION | REFERENCES |
|---|---|---|
| Boundary condition, non-standard | Either a closure or a doublet matching boundary condition. | T-5.7.1, U-B.3.5 |
| Boundary condition, right-hand-side | The specified value of the linear combination of the potential and its derivatives given by the boundary condition. | T-5.7.4 |
| Boundary value problem | The combination of a partial differential (or integral) equation and boundary condition equations on a surface. | T-3.2, U-A.3 |
| Boundary value problem, analysis | A boundary value problem with boundary conditions specifying the normal component of the velocity or mass flux. | U-3.3, U-B.3.2 |
| Boundary value problem, design | A boundary value problem in which the boundary conditions specify the values of a tangential component of the velocity on a surface. | T-C, U-B.3.3 |
| Boundary value problem, ill-posed | A boundary value problem which does not have a unique solution, or has no solution. | T-5.4, T-B.1, U-A.3 |
| Boundary value problem, well-posed | A boundary value problem which has a unique solution. | U-A.3, T-3.2, T-5.4, T-B.1 |

| ITEM | DEFINITION | REFERENCES |
|---|---|---|
| Column index | An integer which, in conjunction with the row index, describes the indicial location of a panel or a panel corner point. When panel corner points are defined by a user, all the points whose column indices are identical are input consecutively. | U-B.1.1, T-5.1 |
| Compressibility direction | The direction of freestream flow in the Prandtl-Glauert equation. It is defined by the input terms "CALPHA" and "CBETA". | T-5.2, U-B.2.1 |
| Compressibility vector | A unit vector in the compressibility direction. | T-5.2 |
| Configuration | The surface (including possible wakes) on which flow boundary conditions are applied or the potential or velocity is discontinuous. | T-5.1 |
| Configuration, image part | That part of a symmetric configuration which is not input by the user. | T-5.7.2, U-2.1.2 |
| Configuration modeling | The process of representing an object, the flow field about which is of physical interest, as a collection of networks of panels on which boundary conditions are applied. | U-3.1, U-B.1, T-B.2, S-2.2 |
| Configuration modeling, exact | The representation of a physical surface with networks of panels describing the exact physical location of the surface. | U-2.1.4, S-3.1.4 |
| Configuration modeling, linearized | The representation of thickness or deflection of a physical surface by means of a mean surface paneling combined with the specification of boundary conditions which simulate the perturbation of the true surface geometry from the paneled surface. | U-2.1.4, S-3.1.4 |
| Configuration, real part | The user-defined (that is, input) part of a symmetric configuration. | T-5.7.2, U-2.1.2 |
| Configuration symmetry | Existence of one or two (perpendicular) planes through which the real part of configuration may be reflected to obtain the complete configuration. | T-5.7.2, U-2.1.2, U-B.2.3, S-3.1.2 |

| ITEM | DEFINITION | REFERENCES |
|---|---|---|
| Configuration, thick | A configuration model in which one surface of a network is exposed to a flow field of interest, while the other surface is exposed to a flow field of no physical interest. | U-2.1.2, T-5.4.2.3, S-3.1.3 |
| Configuration, thin | A configuration model in which both sides of a network are exposed to the flow field of interest. An example arises from the modeling of a wing as a single paneled surface. | U-2.1.2, T-5.4.2.2 S-3.1.3 |
| Conormal vector, $\tilde{n}$ | The vector obtained by a Mach number - dependent transformation of a unit surface normal vector. In compressibility coordinates, $\tilde{n} = (s_B^2 n_x, n_y, n_z)$. | T-5.2, T-E.2 |
| Constraint matrix | The right-hand-side term in a multiple system of boundary condition equations, that is, a system of equations with more than one right-hand-side vector. | T-5.7.4, T-L |
| Constraint number | The right-hand-side term of a single boundary condition equation. | T-3.2 |
| Constraint vector | The right-hand-side term in a system of boundary condition equations with only one right-hand-side vector. | T-3.3, T-5.7.2 |
| Continuity of doublet strength | The condition that a certain alternating sum of doublet strengths along an abutment is zero. This reduces to equality of doublet strengths if two network edges are involved. It permits the elimination of the line vortex term from the integral equation. | T-F |
| Continuity equation | The equation expressing conservation of mass in a small fluid element. | T-2.1 |
| Control points | The points on a configuration surface at which up to two boundary conditions are applied. | T-3.3, T-5.4, T-G |
| Control point, center | A control point whose location is receded slightly from a panel center point. | T-G, U-B.3.4 |
| Control point, corner | A control point whose location is receded slightly from a panel corner point at the end of an abutment. | T-G, U-B.3.4 |

| ITEM | DEFINITION | REFERENCES |
|---|---|---|
| Control point, edge | A control point whose location is receded slightly from a panel edge midpoint on a network edge. | T-G, U-B.3.4 |
| Control points, extra | Control points introduced by the subdivision of a network edge into more than one abutment. | T-5.4, T-G |
| Control point recession vector | A vector which defines the difference between the location of the control point and the location of the point from which it is receded. | T-G |
| Compressible gradient operator, | The gradient operator whose component in the freestream direction has been multiplied by $(1-M^2)$, where M is the freestream Mach number. | T-5.2 |
| Coordinate system, compressibility, (x,y,z) | The coordinate system in which the preferred direction of the Prandtl-Glauert equation is the x-direction. | T-5.2, U-B.2.1 |
| Coordinate system, local, $(x', y', z')$ | A generally non-orthogonal coordinate system used to compute surface integrals for each subpanel, and generally distinct for each subpanel. | T-5.2 |
| Coordinate system, reference, $(x_o, y_o, z_o)$ | An arbitrary rectangular Cartesian coordinate system in which the program user defines the configuration geometry. | T-5.2, U-B.2.1 |
| Coordinate system, scaled, (x,y,z) | The non-orthogonal coordinate system in which the Prandtl-Glauert equation transforms to either Laplace's equation or the wave equation. | T-3.1 |
| Coordinate transformation | A linear transformation, defined by a matrix, which transforms point coordinates from one system to another. | T-E, U-B.2.1 |
| Corrections, velocity | Optional semi-empirical corrections applied to the computed velocity. | U-B.4.1, T-5.9.3, T-N.3 |
| Critical speed | The speed of sound at a particular point in the flow field. | U-B.4.2, T-N.2.4.2 |

| ITEM | DEFINITION | REFERENCES |
|---|---|---|
| Data check | A run of PAN AIR in which the validity of the configuration geometry and boundary conditions is checked without a potential flow solution being attempted. | U-2.3.1 |
| Differentiated influence coefficients | Matrices which define the derivative with respect to panel or control point location of the potential and velocity induced by a panel on a control point. (Not currently used in PAN AIR.) | T-C.3 |
| Dirichlet problem | A boundary value problem consisting of the specification of potential on the boundary of a region of finite volume. | U-A.3 |
| Discretization | A numerical method for solving an integral equation by replacing continuous quantities with discrete ones. | T-2.5, T-3.3 |
| Displacement modeling | The representation of viscous effects such as a boundary layer by a perturbation of the boundary conditions (through the definition of a specified flow) or the surface paneling. | U-2.1.4 |
| Design capability | The ability to specify a desired pressure distribution on a surface whose shape is only known approximately, and obtain a relofted surface which more nearly yields the desired pressure distribution. | U-2.2, T-C, S-1.0 |
| Design, iterative | A multi-step design procedure in which the relofting algorithm makes use of "differentiated influence coefficients". | T-C.3 |
| Design, linearized | A one-step design procedure in which a first order approximation to the desired surface is sufficient. | T-C.1 |
| Design, sequential | A multi-step design procedure in which the relofting algorithm makes use of the normal mass flux which the program computes on the paneled surface. | T-C.2 |
| Domain of dependence | The spatial domain in which disturbances are felt at a particular point P. It consists of all of space in subsonic flow and the upstream Mach cone from P in supersonic flow. | T-5.2 |

| ITEM | DEFINITION | REFERENCES |
|---|---|---|
| Domain of influence | The domain in which disturbances at a point P are felt. It consists of all of space in subsonic flow, and the downstream Mach cone from P in supersonic flow. | T-Figure 5.4 |
| Doublet distribution | One of the two unknown quantities in the fundamental integral equation. | T-3.2, U-A.2 |
| Doublet matching | See boundary condition, doublet matching. | U-B.3.5 |
| Doublet parameters | Unknown quantities on which the doublet distribution on the configuration depends. | T-5.5 |
| Doublet strength | The value of the doublet distribution at a particular point. It is equal to the size of the jump in velocity potential across the surface. | T-3.1, U-A.2 |
| Drag | The x-component of the force on the configuration in the wind axis system. PAN AIR computes drag on an impermeable surface by integrating the pressure distribution on the surface. The drag computed by PAN AIR does not include viscous effects. | U-2.1.7 |
| Dual vector | A real-valued linear function on a vector space. Dual vectors transform according to equation (E.1.8e) of the Theory Document. Typical dual vectors are the gradient operator and the surface normal. A dual vector is also known as a covariant vector. | T-E.1 |
| Dual vector, almost | A vector transforming according to equation (E.1.12) of the Theory Document. | T-E.1 |

| ITEM | DEFINITION | REFERENCES |
|---|---|---|
| Edge conormal | A vector lying in the plane of the panel or subpanel whose "pseudo-inner product" with the edge tangent is zero. | T-J.5.1 |
| Edge function | One of the two basic components (along with the panel function) of the entries of a PIC matrix. It is defined by an integral along a panel or subpanel edge. | T-J.7 |
| Edge force computation | A special computation of forces on the edge of a thin surface, where the small perturbation assumptions may not be valid. | T-5.9.4, T-0.3, U-B.4.3 |
| Edge matching | The problem of imposing appropriate conditions on singularity strength variation across network edges. | T-2.2, U-B.3.5 |
| Edge, nearly sonic | A subpanel or panel edge for which the pseudo-inner product of the edge tangent with itself is approximately zero. Such an edge can only occur in supersonic flow, and is inclined to the flow at approximately the same angle as a Mach cone. | T-J.5.1 |
| Edge, network | That collection of panel edges lying on one extreme of a network and thus not shared by two adjoining panels. | T-D.1, U-B.1.1 |
| Edge normal | A vector lying in the plane of the panel or subpanel and perpendicular to the edge. | T-J.5.1 |
| Edge, panel | A line segment connecting two panel corner points. | T-D.1 |
| Edge, subsonic | A subpanel or panel edge for which the "pseudo-inner product" of the edge tangent with itself is positive. | T-J.5.1 |
| Edge, supersonic | A subpanel or panel edge for which the pseudo-inner product of the edge tangent with itself is negative. Such an edge can only occur in supersonic flow, and is inclined to the flow at a greater angle than the Mach cone. | T-J.5.1 |
| Edge tangent | A unit vector parallel to a panel or subpanel edge. | T-J.5.1 |

| ITEM | DEFINITION | REFERENCES |
|---|---|---|
| Energy equation | An equation expressing conservation of energy in a small fluid element. | T-2.1 |
| Entrainment | The phenomenon in which an efflux from a propulsion source absorbs fluid from the surrounding flow as the distance from the configuration increases. | U-2.1.4 |
| Equation of state | An equation relating the pressure, density, and temperature of a fluid. | T-2.1 |
| Euler's equation | A differential equation relating density, velocity, and pressure in a fluid (momentum equation for inviscid fluid without body forces). | T-2.2 |
| Existence of a solution | The problem of determining whether a boundary value problem has at least one solution. | T-B.1, U-A.3 |
| Extension matrix, doublet | A matrix which gives the values of doublet strength at the corners of a subpanel and the "kappa quantities" for its edges in terms of the panel doublet parameters. | T-I.2.2.4 |
| Extension matrix, source | A matrix which gives the values of source strength at the corners of a subpanel in terms of panel source parameters. | T-I.2.1.3 |

| ITEM | DEFINITION | REFERENCES |
|---|---|---|
| Far field method | An approximation for the computation of panel influence based upon the distance of the control point from the panel being much greater than distances within panel. | T-4.2.2, T-5.6, T-J.9 |
| Far field moment, subpanel | A matrix or tensor which describes the dependence of a particular integral over a panel on the panel source or doublet parameters. | T-I.4.2.1 |
| Far field moment, basic | Scalars giving the values of certain integrals of polynomial functions over a subpanel. | T-I.4.3 |
| Far field moment, subpanel | A matrix or tensor which describes the dependence of the same integral over a subpanel on the panel singularity parameters. | T-I.4.2.1 |
| Flow symmetry | The existence of one or two (orthogonal) planes of symmetry for the flow field. | T-5.7.2, U-2.1.2, U-B.2.1 |
| Force | For impermeable surfaces, the force is the integral over the surface of the pressure times the surface normal vector. For permeable surfaces, an additional "momentum transfer" term contributes to the force. | U-2.1.7, T-O |
| Force coefficient | A normalized form of the force vector which removes the force due to the freestream flow and allows for a scaling factor introduced by the user. The force coefficient on an impermeable surface is the integral of the pressure coefficient times the normal vector divided by a user-supplied reference area. | T-O.1, U-B.4.3 |
| Force, edge | See edge force computation. | |
| Freestream, $\vec{V}_\infty$ | The uniform flow which is perturbed by the introduction of a configuration on which boundary conditions are imposed. See also onset flow, uniform, and velocity perturbation. | T-2.3 |

| ITEM | DEFINITION | REFERENCES |
|---|---|---|
| Global data | Information (such as symmetry plane locations and the compressibility direction) supplied by the PAN AIR user to describe the configurations as a whole. | U-7 |
| Gradient operator, $\vec{\nabla}$ | A vector whose entries are the partial differentiation operation with respect to the coordinate functions. | T-B.3 |
| Grid points | Panel corner points. | T-5.1, U-B.1.1 |
| Grid points, fine or enriched | Rectangular array of points which are corner points, edge midpoints, or center points of quadrilateral (or triangular) panels of a network. | T-5.1, U-B.1.1 |
| Green's theorems | Several relations between spatial integrals and surface integrals. These relations are used to derive the integral equation (B.0.1) of the Theory Document, which PAN AIR solves numerically. | T-3.2 |

| ITEM | DEFINITION | REFERENCES |
|---|---|---|
| Influence coefficient | A matrix giving one or more field flow properties as a linear combination of the array of singularity parameters. | T-5.6 |
| Influence coefficient, aerodynamic, AIC | Combination of potential and velocity influence coefficient matrices giving left-hand-side of boundary condition equation as a linear combination of singularity parameters. | T-3.3, T-4.2, T-5.7 |
| Influence coefficient, panel, PIC | Matrix giving perturbations that a source or doublet distribution on a panel induces at a control point. | T-4.2.2, T-5.6, T-J |
| Influence coefficient, potential, $\phi$IC | Matrix giving the perturbation velocity potential at network control points as a linear combination of singularity parameters. | T-4.2, T-5.6 |
| Influence coefficient, velocity, | Same for perturbation velocity. | T-4.2, T-5.6 |
| Intermediate field method | Approximation for computation of panel influence; intermediate between near field and far field methods. | T-5.6, T-J.9 |
| Irrotational flow | Property that the curl of the velocity field is zero; assure existence of velocity potential. | Y-2.3 |

| ITEM | DEFINITION | REFERENCES |
|---|---|---|
| Jet efflux | A flow emanating from the propulsion unit. A jet efflux may be modeled in PAN AIR by paneling the jet efflux with a wake network. | U-2.1.1 |
| Jet efflux tube | The cylindrical surface surrounding the jet efflux, extending from the configuration to infinity. | U-2.1.1 |

| ITEM | DEFINITION | REFERENCES |
|---|---|---|
| Kappa quantity | A quantity defined for a line segment (generally a panel or subpanel edge) on which a quadratic function is defined. The value of the quantity is the value of the function at an endpoint of the segment plus half the gradient of the function dotted into the difference vector between the positions of the two endpoints. | T-I.2.2.2 |
| Kutta condition | The boundary condition imposed at the trailing edge of a lifting surface such as a wing, specifying that the jump in pressure coefficient be zero there. | U-A.2, T-B.2 |

| ITEM | DEFINITION | REFERENCES |
|---|---|---|
| Laplace's equation | Fundamental partial differential equation saying that divergence of gradient of a scalar is zero. | T-3.2, U-2 |
| Least squares fit, constrained | The process of fitting a function as well as possible to a set of values at a point on a plane. The values need not be known in advance; the result of the process is a matrix giving the defining coefficients of the function in terms of the unknown values. | T-I.1.2.1, T-I.5.1 |
| Length, reference | A user-input length for the scaling of moment coefficients computed by the program. | T-0.1, U-B.4.3 |
| Line vortex term | The line integral in the expression for velocity at a point in space. This integral vanishes if doublet continuity is maintained everywhere. | T-5.6, T-B.3, U-A.2 |
| Lofting | The revision of the geometry of a surface to more nearly attain a pressure distribution specified in a design run. | T-C.2 |

| ITEM | DEFINITION | REFERENCES |
|---|---|---|
| M-direction | The direction of increasing panel row index. | U-7.4, U-B.1.1 |
| Mach angle | The angle formed between the freestream direction and a Mach line. | T-J |
| Mach cone, upstream | A right circular cone located upstream of a field point, containing domain of dependence of that point, in supersonic flow. | T-5.2 |
| Mach disk | The interior of the circle resulting from the intersection of a Mach cone with a plane perpendicular to its axis. | T-J.4.2 |
| Mach - inclined surface | A surface whose normal is perpendicular to its conormal ($\hat{n} \cdot \tilde{n} = 0$). Such a surface is tangent to a Mach cone. | T-5.2, U-B.1.3 |
| Mach line | A straight line generator of the Mach cone. One of the lines of intersection of the Mach cone with a plane containing the origin point of the cone. | T-J |
| Mach number | The ratio of the speed of the fluid to the speed of sound. | T-2.3 |
| Mach wedge | The set of all point affected by a disturbance on a supersonic edge. The Mach wedge emanates fownstream from the edge. A point Q lies in the Mach wedge if some point P on the edge lies in the domain of dependence of Q. | T-J.11 |
| Mass flux, linearized perturbation, $\vec{w}$ | The vector obtained by applying the compressible gradient operator to the velocity potential, or by scaling the freestream component of the perturbation velocity by $(1-M_\infty{}^2)$. In compressibility coordinates $\vec{w} = (s\beta^2 u, v, w) = \vec{\nabla}\phi$. | T-5.4 |
| Mass flux, total, $\vec{W}$ | Produce of local density (normalized by freestream density) and velocity of fluid, $\vec{W} = (\rho/\rho_\infty)\vec{V} = \vec{V} + \vec{w}$. | T-4.5 |
| Matrix decomposition | Expression of a square matrix as product of lower and upper triangular matrices. | T-5.8 |

| ITEM | DEFINITION | REFERENCES |
|---|---|---|
| Metric matrices | Matrices which account for compressibility effects. The first metric matrix (denoted B) multiplies the freestream component of a vector by $(1-M_\infty^2)$, while the second metric matrix (denoted C) multiplies the component of the vector perpendicular to the freestream by $(1-M_\infty^2)$. | T-E.2 |
| Minimal data set | A small amount of data (potential, normal mass flux, source and doublet strength) stored for each solution and each control or grid point in anticipation of post-processing. | T-M, U-2.1.1 |
| Modified data set | A small amount of data (potential, normal mass flux, source and doublet strength) stored for each solution and each control or grid point in anticipation of post-processing. | T-M, U-2.3.4 |
| Modeling | See configuration modeling. | |
| Modified dual vector | A dual vector whose component in the freestream direction has been sealed by $(1-M_\infty^2)$. A modified dual vector is obtained from a dual vector by the application of the first metric matrix. | T-E.2 |
| Modified vector | A vector whose component perpendicular to the freestream has been sealed $(1-M_\infty^2)$. A modified vector is obtained from a vector by the application of the second metric matrix. | T-E.2 |
| Moment coefficient, $C_m$ | An angular momentum analog of the force coefficient. The moment coefficient contains a user-supplied scaling factor, and is defined by equation (0.1.3) of the Theory Document. | T-0.1, U-B.4.3 |
| Momentum equation | Equation expressing conservation of linear momentum in a small fluid element. | T-2.1 |
| Multiply connected | A region of space is multiply connected if a closed path can be drawn be in the region which cannot be shrunk to a point. See also "simply connected." | T-B.1, U-A.3 |

| ITEM | DEFINITION | REFERENCES |
|---|---|---|
| N-direction | The direction of increasing panel column index. | U-7.4, U-B.1.1 |
| Navier - Stokes equation | Combination of continuity, momentum, and energy equation for a fluid. | T-2.1 |
| Near field method | Computation of a panel influence coefficient matrix by summing over all eight subpanels the influence of each subpanel. | T-J.1 |
| Network | An indically rectangular array of panels corner points; basic unit for defining the geometry of the configuration. | T-5.1, U-B.1.1, T-D.1 |
| Network, analysis | Network with singularity parameter locations as required for analysis boundary conditions. | T-5.1 |
| Network, composite | Network having both source and doublet distributions. | T-5.1 |
| Network, design | Network with singularity parameter locations as required for design boundary conditions. | T-5.1 |
| Network, doublet | Network having a (locally quadratic) doublet distribution. | T-5.1 |
| Network gaps | Gaps due to non-coincidence of network edges. | T-4.1, T-5.3 |
| Network, wake | See wake network. | |
| Network, source | Network having a (locally linear) source distribution. | T-5.1 |
| Network type, doublet | A description of the function performed by the doublet distribution on the network. Doublet types existing are analysis, design, wake, and null (zero doublet distribution). | T-5.1, T-D |
| Network type, source | Same for source distribution. Types are analysis, design, and null. | T-5.1, T-D |
| Network, wake | Network used to model wake surfaces: has continuous normal flow, may have discontinuity in potential across network. | T-5.1, U-B.1.1 |
| Normal vector, unit | See unit normal vector. | |

| ITEM | DEFINITION | REFERENCES |
|---|---|---|
| Onset flow, $\vec{U}$ | The user-defined flow field in which the configuration is analyzed. In the simplest case, this is just the uniform freestream flow $\vec{V}_\infty$. | U-B.2, T-H.3, S-3.1.5 |
| Onset flow, local incremental $\Delta\vec{U}$ | A supplementary term added to the onset flow at individual control points to simulate the superposition of a non-uniform effect (such as a slipstream) onto the freestream. | U-B.2, T-H.3 |
| Onset flow, rotational | A supplementary term added to simulate a rolling or pitching motion. | U-B.2, T-H.3 |
| Onset flow, total, $\vec{U}_O$ | The sum of all terms in the onset flow. | U-3.2.1 |
| Onset flow, uniform, $\vec{U}_\infty$ | An onset flow which is constant over the entire flow field, and is used to simulate a uniform freestream. The uniform onset flow need not be parallel to the freestream direction $\vec{V}_\infty$ on which compressibility effects are based. | U-B.2, T-H.3 |

| ITEM | DEFINITION | REFERENCES |
|---|---|---|
| Panel | Part of a network surface, defined by four network defining points which are indicially adjacent. | T-3.3, T-4.1, T-5.1, T-D.1 |
| Panel, almost non-convex | A panel with an interior angle of nearly $180^{o}$. | U-B.1.3, T-D.2 |
| Panel aspect ratio | The ratio of the length of a panel to its width. | U-B.1.3, T-D.2 |
| Panel center point | The point whose coordinates are the average of the coordinates of the four panel corner points. | T-D.1 |
| Panel column | A sequence of panels with the same column index. See column index. | U-B.1.1, T-5.1 |
| Panel corner point | One of the grid of points which defines a network. Four of these points (appropriately adjacent in an indicial sense) are sufficient to construct a panel's geometry. | T-D.1 |
| Panel defining points | The corner points, edge midpoints, and center point of a panel. | T-D.2 |
| Panel diameter | Twice the panel radius. | T-D.2 |
| Panel edge midpoint | The midpoint of a segment connecting adjacent panel corner points. | T-D.1 |
| Panel function | One of the two basic components (along with the edge function) of the entries of a PIC matrix. Defines as an integral over a panel or subpanel. | T-J.7 |
| Panel integral matrix | Matrix giving the velocity and/or potential induced at a control point by a panel or subpanel, in terms of the coefficients of the polynomial describing the source or doublet strength on the region. | T-J.6 |
| Panel method | Method for solving potential flow problems, using panel model of surface to reduce integral equation to a system of linear equations. | T-1.0, T-4.1 U-A.2 |

| ITEM | DEFINITION | REFERENCES |
|---|---|---|
| Panel, non-convex | A panel containing interior angles exceeding $180^{o}$. | U-B.1.3, T-D.2 |
| Panel radius | The distance. | T-D.2 |
| Panel skewness parameters | Real numbers whose magnitude describe the extent to which a panel fails to be a parallelogram. | T-D.2 |
| Panel, subinclined, superinclined, or Mach-inclined | See subinclined, superinclined, or Mach-inclined surface. | |
| Panel, triangular | A panel two of whose corner points coincide. | U-B.1.1 |
| Parameterization | See *abutment parameterization*. | T-J.4.4.2 |
| Perturbation | Change to undisturbed flow field or geometry. | T-2.3, T-A.1 |
| Phase function | Function with two arguments equivalent to the FORTRAN function ATAN2 with arguments reversed. Phase (x,y) = arg(x+iy), where arg is the argument of a complex number. | T-J.4.4.2 |
| Post-processing | The computation of pressures, or forces and moments from the minimal data set. | U-2 |
| Potential | See velocity potential. | |
| Potential flow | Fluid flow characterized by the existence of a velocity potential function, satisfying a particular partial differential equation, whose gradient at a point is the velocity there. | T-2, T-A |
| Prandtl-Glauert equation | Partial differential equation for compressible flow: divergence of compressible gradient of perturbation velocity potential is zero. | T-2.5, T-A, S-2.0, U-A.1 |

| ITEM | DEFINITION | REFERENCES |
|---|---|---|
| Preferred direction | In the solution of the potential flow problem (that is, the construction and solution of the system of linear equation), it is the compressibility direction. In post-processing, it is the user-specified x-direction in which velocity = (u,v,w) for the computation of the pressure coefficient. | T-H.3, U-B.2.1 |
| Pressure, P | Force per unit area. | T-N.1, U-B.4.2 |
| Pressure coefficient, Cp | A normalized expression for pressure which removes the contribution of the freestream flow to the pressure. | T-N.2.1, U-B.4.2 |
| Pressure coefficient, isentropic | A formula for pressure coefficient resulting from certain basic assumptions about the character of the fluid flow. | T-N.2.1, U-B.4.2 |
| Pressure coefficient, linear | A formula for pressure coefficient resulting from the additional assumption that second order terms in perturbation quantities are negligable. | T-N.2.5, U-B.4.2 |
| Pressure coefficient, reduced second order | A formula for pressure coefficient based on the second order assumption and the additional assumption that terms containing the Mach number squared are negligable. | T-N.2.5, U-B.4.2 |
| Pressure coefficient, second order | A formula for the pressure coefficient resulting from the additional assumption that third powers of perturbation quantities are negligable. | T-N.2.4, U-B.4.2 |
| Pressure coefficient, slender body | A formula for pressure coefficient based on the second order assumption and the additional assumption that second order terms in the component of velocity parallel to the freestream are negligable. | T-N.2.5, U-B.4.2 |
| Pressure coefficient, vacuum | The most negative value the isentropic pressure coefficient can attain. | U-B.4.2, T-N.2.4.1 |
| Pseudo-inner product | Modified inner product, one of whose terms in scaled to account for compressibility. | T-J.5.1 |

| ITEM | DEFINITION | REFERENCES |
|---|---|---|
| Recession vector | See control point recession vector. | |
| Refinement of paneling | The paneling along one network edge is a refinement of the paneling along a second network edge on the same abutment if the first edge has a panel corner point wherever the second edge has a panel corner point. | T-I.1.2.5 |
| Region, exterior | Spatial region outside a finite surface. | T-3.2 |
| Region, interior | Spatial region inside a finite surface. | T-3.2 |
| Right-hand-side | See boundary condition, right-hand-side. | |
| Row index | An integer which, in conjunction with the column index, describes the indical location of a panel or panel corner point. When the panel corner points are input by the user all points with the same column index are input consecutively. For each column of points input by the user, the row index runs consecutively from 1 to the maximum row index. | T-5.1, U-B.1.1 |

| ITEM | DEFINITION | REFERENCES |
|---|---|---|
| Shear layer | A surface in the flow field on which the velocity tangential to the surface is discontinuous. A shear layer is modeled in PAN AIR by means of a wake network. | U-2 |
| Simply connected | A region of space in which any path may be shrunk to a point. See also "mulitply connected" and Figure B.8 of the Theory Document. | T-B.1, U-A.3 |
| Singularity parameters | Unknown in system of linear equations constructed by a panel method. | T-3.3 |
| Singularity parameters, unknown | Singularity parameters specified by a single boundary condition equation. | T-5.7.2, T-5.7.3, T-K.2 |
| Singularity parameter, panel | The value of source strength at one of five panel points (corners or center) or the value of doublet strength at the nine panel defining points. | T-I.1, T-I.2 |
| Singularity type | The source of doublet type of network. This may be analysis, design, wake 1 or wake 2 (for doublets only), or null. | U-A.2 |
| Slipstream | The flow field induced by a rotating propeller. | T-H.3 |
| Small perturbation assumptions | Assumptions that certain quantities are small enough that their higher powers may be ignored. The Prandtl-Glauert equation holds for irrotation, isentropic, inviscid flow in which certain small perturbation assumptions have been satisfied. | T-A.1 |
| Solution list | A list of different constraints under which the system of linear equations is to be solved. Typically, a list of solutions might consist of several angles of attack and/or sideslip. | U-7 |
| Solution vector | The vector of unknowns in the system of linear equations. | T-5.7.4 |
| Source distribution | One of two unknown quantities in the fundamental integral equation. | T-3.2, U-A.2 |

| ITEM | DEFINITION | REFERENCES |
|---|---|---|
| Source parameters | Known or unknown quantities on which the source distribution on the configuration depends. | T-5.5 |
| Source strength, $\sigma$ | The value of the source distribution at a particular point. It is equal to the size of its jump in normal mass flux across the surface. | T-3.2, U-A.2 |
| Specified flow, b | The right-hand side term in a boundary equation. That is, some combination of potential and velocity is specified by the equation to equal b. | U-B.3 |
| Spline | The method by which a function on a surface is obtained from the specification of values of the function at a discrete set of points on the surface. | T-I |
| Spline, edge | The method by which doublet spline vectors are constructed for five grid points on the edge of a network. | T-I.1.2 |
| Spline matrix, outer | A matrix giving values of (five source or nine doublet) panel singularity parameters values in terms of surrounding singularity parameters. | T-I.1 |
| Spline matrix, subpanel (or panel or half panel) | A matrix giving the singularity distribution on subpanel (or panel or half panel) in terms of panel singularity parameters. | T-4.2.1.1, T-5.5, T-I.2, T-I.3.1, T-I.3.2 |
| Spline, two-dimensional | The method by which a function on a line segment is obtained from the specification of values of the function at a discrete set of points on the line segment. | T-C.4 |
| Spline vector | A row vector giving source or doublet strength at a fine grid point in terms of surrounding singularity parameters. | T-I.1 |
| Stability | The property of a spline, in conjunction with a set of boundary conditions, that a perturbation in the boundary conditions at one point causes a disturbance in the solution which decreases rapidly with distance from the point. | T-C.4 |

| ITEM | DEFINITION | REFERENCES |
|---|---|---|
| Stagnation to ambient | Flow which is no faster than freestream (ambient) flow, yet not highly perturbed as to have a negative component in the freestream direction. Such a flow may be corrected using the semi-empirical "velocity corrections". | U-B.4.1 |
| Stagnation, perturbation | A point at which the perturbation velocity is zero. | T-5.4.2.3 |
| Stagnation, total | A point at which the total velocity is zero. | T-5.4.2.3 |
| Subinclined surface | A surface for which the inner product of normal and conormal is positive. All surfaces are subinclined in subsonic flow. | U-B.1.1, T-5.2 |
| Subpanel | A flat triangular surface which is the basic unit of the panel analysis in PAN AIR (a panel consists of eight subpanels). | T-4.2.1.1, T-5.1 |
| Subpanel, subinclined, superinclined, or Mach-inclined | See subinclined, superinclined, or Mach-inclined surface. | |
| Subsonic flow | Flow for which the Mach number is less than one. | T-3.1, U-2.0, S-1.0 |
| Superinclined surface | A surface for which the inner product of normal and conormal is negative. Such a surface is inclined to the freestream at more than the Mach angle. | U-B.1.1, T-5.2 |
| Supersonic flow | Flow for which the Mach number is greater than one. | T-3.1, U-2.0, S-1.0 |
| Surface, lower | The side opposite to the upper surface. | T-5.4, U-A.3.1 |
| Surface, upper | The side of the surface bounding the region into which the unit normal points. An exception is that for post-processing only, upper and lower surfaces are switched by means of the "reverse" option. | T-5.4, U-A.3.1 |
| Symmetry, plane of | A plane such that either the flow or the configuration geometry is left unchanged if reflected in this plane. | U-2.1.2, U-B.2.3, T-K.1 |

| ITEM | DEFINITION | REFERENCES |
|---|---|---|
| Tangent vector | A vector perpendicular to the surface normal. | T-5.4 |
| Thick body | See configuration, thick. | |
| Thin body | See configuration, thin. | |
| Tolerance distance | A distance supplied by the user. The program searches for network edges which lie closer together than the tolerance distance, and forms pairwise abutments for these edges. | T-F.2, U-3 |
| Total | The sum of a freestream quantity and a perturbation quantity. | U-A.1 |
| Transformation, orthogonal | A length-preserving coordinate transformation. | T-E.3 |

| ITEM | DEFINITION | REFERENCES |
|---|---|---|
| Update, IC | The capability allowing reuse of AIC's for some networks when modifying other networks. | T-5.7.5, T-K.6, S-3.3.3, U-2.3.2 |
| Update, solution | Capability of storing AIC's and reusing them later in a new problem in which only the boundary condition constraints have been changed. | U-2.3.2, T-L, T-5.8, S-3.3.2 |
| Unit normal vector, $\hat{n} = (n_x, n_y, n_z)$ | A vector of length 1 which is perpendicular to a surface. Its direction is defined as the direction of increasing column index cross the direction of increasing row index. | T-D.2 |

| ITEM | DEFINITION | REFERENCES |
|---|---|---|
| Velocity $\vec{V}$ | The time rate of position change of fluid particles. | T-2.1, U-A.1 |
| Velocity computation method | One of two methods of computing the velocity at a point from the minimal data set. The boundary condition method attempts to obtain data from boundary conditions and spline it, while the VIC method obtains the velocity from the product of a velocity influence coefficient matrix with the vector of singularity parameters. | U-2.1.6 |
| Velocity, perturbation, $\vec{v}$ | The difference between total velocity and that of the undisturbed fluid. | T-2.3, U-A.1 |
| Velocity potential, $\phi\vec{\Phi}$ | The function whose gradient is the velocity, $\vec{v} = \vec{\nabla}\phi$, $\vec{V} = \vec{\nabla}\Phi$ . | T-2.3, U-A.1 |
| Vorticity, surface, $\vec{\gamma}$ | The cross product of surface normal vector and doublet gradient, $\vec{\gamma} = \hat{n} \times \vec{\nabla}\mu$. | U-A.2, T-5.6.2 |

| ITEM | DEFINITION | REFERENCES |
|---|---|---|
| Wake, physical | A sheet of vorticity shed from the physical configuration. | T-5.1, T-B.2 |
| Wake network | A network used by PAN AIR to model a physical wake. The normal mass flux is continuous on such a network, while the potential and tangential velocity may be discontinuous. | T-5.1, T-B.2 |
| Wave equation | A particular hyperbolic partial differential equation. PAN AIR solves this equation when the Mach number is $\sqrt{2}$. | T-3.1 |
| Wetted surface | A surface is wetted by a region of space of it borders on that region. | U-A.3 |

# 10.0 SOFTWARE GLOSSARY

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| Key Word | Description |
|---|---|
| Abutment | A curve where two or more network edges (exactly or approximately) meet. |
| Abutment Intersections | Points where several abutments meet. |
| Account numbers | Computing center cost accounting labels. |
| Address | The software identification of a word in central memory. |
| Array | A collection of contiguous words in central memory. |
| B (Outer) Spline | A matrix which gives the value of source or doublet strength at panel grid points in terms of surrounding singularity parameters. |
| BP-Spline | A row vector giving a flow quantity at a grid point in terms of the flow quantities at surrounding control points. |
| Block Partition Format | The arrangement of a coefficient matrix as a collection of rectangular submatrices. |
| Buffer | An area of storage which temporarily holds data that will be subsequently delivered to a processor. |
| Calling relationship | The set of all subprograms invoked by a program unit. |
| CDC Cyber 175, 6600, 7600 | Control Data Corporation data processing systems. |
| Closure Condition | A non standard boundary condition imposed to insure a design network edge will remain unchanged after the geometry has been relofted. |
| Communication Vehicle | A method of data transfer between subprograms. |
| Compass | The CDC Assembly language. |
| Compilation | The translation of a high level source language, like FORTRAN IV, into machine language. |

| Key Word | Description |
|---|---|
| Compressibility Direction | The direction of freestream flow in the Prandtl-Glauert equation. It is defined by the input terms "CALPHA" and "CBETA." |
| Compressible Inner Product | An inner product with respect to the compressibility coordinate system. |
| Constraints | Right-hand-side values for boundary condition equations. |
| Control Card Stream | A sequence of control statements. |
| Control Statement | A user instruction to the operating system. |
| Core | Semi-conductor memory which is manipulated by the central processing unit. |
| CPU (Central Processor Unit) | Elements of a data processing system that carry out a variety of essential data manipulations and controlling tasks. |
| Data Base Communication Chart | A tabular listing which correlates datasets and the subprograms which use them. |
| Data Base Directive | A user directive which may specify the file identification parameters for the PAN AIR databases and the master definitions. |
| Data Base Information Table | A tabular listing of the specifications made by the data base directives. |
| Data Base Management System | A piece of software which manages data bases in direct access storage. |
| Data Base status | The completeness of the information in a data base. |
| Data flow | The relationship of the output data of one program to the input data of another program. |
| Dataset | A collection of element sets and their associated key sets. |
| Design Code | See pseudo code. |

| Key Word | Description |
|---|---|
| Diagnostic message, warning message | Program identification of an abnormality detected during execution which will not result in program termination. |
| Disk | A computer storage medium external to the CPU. |
| Element | The basic informational unit of an SDMS data base. |
| Element Set | A well defined collection of elements. |
| 'end of record' card | The delimiter between sections of a job input file. |
| Executable Code | FORTRAN statements which specify actions the program is to take. |
| Execution | The operation of the CPU under control of a program. |
| Execution time | The wall clock time at which a program is in execution. |
| Executive Directive | A user directive which specifies the type of PAN AIR analysis. |
| Executive Module | The component of a software system which controls the execution of other system components. |
| Fatal error | An abnormality detected by the program during execution which results in program termination. |
| Flow quantity | Surface potential, velocity or normal mass flux. |
| Formal Parameters | Arguments which appear in calling sequence of SUBROUTINE or a FUNCTION. |
| FORTRAN IV | A procedure-oriented language supported by CDC compilers. |
| Free field format | The interpretation of program input by its content instead of position. |
| Functional Decomposition | The breakdown of a major computing task into basic computing functions. |
| Glossary | A section of the program preface which describes program variables. |

| Key Word | Description |
|---|---|
| Heterogeneous | The condition of the specified flow data set of the DIP data base when smearing has not been employed. |
| Homogeneous | The condition of the specified flow data set of the DIP data base after smearing has been employed. |
| IC Matrix | A matrix giving one or more field flow properties as a linear combination of the array of singularity parameters. |
| Input | Data used downstream from a given PAN AIR module. |
| JCL (Job Control Language) | The criteria for defining the set of all syntactically correct control statements. |
| Key | An element set identifier. |
| Key Set | A collection of keys which uniquely identify an element set. |
| Library | See program library. |
| Load | Transform a program held on some external storage medium into the main memory of the machine in a form suitable for execution. |
| Macro-options | A data set of the MEC data base which will inform all downstream PAN AIR modules of an IC-update, solution update or post-solution run. |
| Main program | A program which is not a subprogram. |
| Main Overlay | The overlay which is loaded initially and remains in core. |
| Maintainability | Resilience to internal changes |
| Map | A correlation between SDMS dataset elements and program variables. |
| Masking | A bit by bit logical operation on one or more words in central memory. |
| Master Definition File | A collection of data records which defines the structure of a permanent/temporary data base. |

| Key Word | Description |
|---|---|
| MEC Directives | Data base directives and executive directives. |
| Modular Code | Software which has localized the impact of changes in its operating environment. |
| Module | One of the ten basic programs of the PAN AIR system. |
| NOS, NOS/BE, SCOPE | Control Data Corporation operating systems. |
| Operating System | The computer system software that assists the hardware to implement various supervisory and control functions it performs for the tasks created by the users. |
| Out-of-core Matrix Multiplication | The computation of the product of two out-of-core matrices (stored on SDMS data bases). |
| Output | Data used downstream from a given PAN AIR module. |
| Overlay | A portion of a program written on a file in absolute form and loaded at execution time without relocation. |
| PAN AIR Problem | The computation of a numerical solution to the Prandtl-Glauert equation and boundary condition equations over a surface configuration. |
| Permanent (Temporary) Data Base | A well defined data structure, generated by a particular PAN AIR module, which will (not) remain accessible after the job has run to completion. |
| Plot data file | Input data to plotting software. |
| Preface | Software documentation presented as comment statements at the beginning of each PAN AIR module. |
| Primary Overlay | An overlay which may be called into core only by the main overlay and is loaded immediately following the main overlay. |
| Procedure | A collection of control statements, separate from the job control statement section, that may be called by a control statement. |

| Key Word | Description |
|---|---|
| Procedure File | A collection of data records which may be called as a procedure. |
| Program | A collection of FORTRAN statements, with optional comments, terminated by an END statement. |
| Program Library | A collection of computer programs made available to computer users to reduce the work of programming. |
| Program Tree Structure | The schematic representation of calling relationships between subprograms of a module. |
| Pseudo Code | A user-defined, non compilable shorthand for use in defining the flow of a program segment. |
| Secondary Overlay | An overlay which may be called into core only by a primary overlay and is loaded immediately following the primary overlay. |
| Smearing | The application of a single specified flow value to a subset of control points. |
| Software System | An integrated collection of programs which perform a major computing task. |
| Solution data | Basic flow quantities associated with a particular set of right-hand-side equality constraints. |
| Stand-alone program | A program module which may be executed independent from other modules. |
| Structured Programming | Software development which has employed disciplined program organization and notation to facilitate correct and clear descriptions of data and control structures. |
| System Architecture | The construction of a computing system by assembling basic modules. |
| Submodule | A subprogram of a PAN AIR module. |
| Subprogram | A program unit that begins with a SUBROUTINE, FUNCTION or BLOCK DATA statement. |

| Key Word | Description |
|---|---|
| Subroutine | A subprogram unit that begins with a SUBROUTINE statement. |
| Symmetrize | Transform a large system of linear equations into smaller systems of linear equations, by using symmetric properties of the coefficient matrix. |
| Transportability | Resilience to external changes. |
| Tree Diagram | See program tree structure. |
| Unsymmetrize | Transform the solutions of symmetrized systems of linear equations into the solution of the original system. |
| User Directives | A collection of user specifications which define a particular PAN AIR problem and its computing environment. |

## 11.0 List of Symbols

| | |
|---|---|
| a | coefficient of normal mass flux in boundary condition equation |
| a' | coefficient of normal mass flux in closure equation |
| [AIC] | aerodynamic influence coefficient matrix |
| b | constraint in a boundary condition equation |
| b | vector of constraints in a system of equations |
| [B] | matrix of constraint vectors |
| BAS | body axis system (DIP record FM3) |
| BR | span reference parameter (DIP record FM2) |
| c | coefficient of potential in boundary condition equation |
| $\hat{c}_o$ | unit vector in compressibility direction |
| $C_p$ | pressure coefficient |
| $C_{po}$ | known value of pressure coefficient |
| $C_{pv}$ | vacuum (minimum) value of pressure coefficient |
| $\vec{C}_F$ | force coefficient vector |
| $\vec{C}_M$ | moment coefficient vector |
| CR | chord reference parameter (DIP records FM2 and FM11) |
| d | coefficient of tangential velocity in boundary condition equation |
| ds | differential of surface area |
| e | coefficient of normal velocity in boundary condition equation |
| $\Delta E$ | energy added by incremental onset flow |
| FX,FY,FZ | components of force coefficient vector |
| I,i | row index |
| $\vec{I}_F, \vec{I}_M$ | integrals related to force and moment coefficient vectors |
| J,j | column index |
| M | number of rows of panel corner points (grid points) in a network |

| | |
|---|---|
| $\bar{M}$ | vector at network origin in direction of first column of panel corner points |
| MX,MY,MZ | components of moment coefficient vector |
| $M_\infty$ | freestream Mach number |
| n | panel normal coordinate |
| $\hat{n}$ | unit vector normal to panel, outward-pointing from upper surface |
| $\tilde{n}$ | conormal vector of a panel |
| $\hat{n}_s$ | outward-pointing unit vector normal to panel surface |
| N | number of columns of panel corner points (grid points) in a network |
| $\bar{N}$ | vector at network origin in direction of first row of panel corner points |
| p | pressure, newtons/$m^2$ |
| $p_\infty$ | pressure in the freestream, newtons/$m^2$ |
| P | point in space |
| POS | plane of configuration symmetry |
| Q | arbitrary point on panel or on integration surface |
| $\vec{r}$ | field point |
| $\vec{r}_o$ | rotation reference point (DIP record set G6) |
| R(P,Q) | hyperbolic (compressible) distance between P and Q |
| $\vec{R}_o$ | moment reference point (DIP record FM3) |
| RCS | reference coordinate system |
| s | coordinate on a surface |
| s | sign $(1-M_\infty^2)$ |
| $s_i$ | = ± 1, sign corresponding to network edge in an abutment |
| SAS | stability axis system |
| SR | area reference parameter (DIP records FM2 and FM11) |
| t | tangential coordinate on a surface |
| $\vec{t}$ | coefficient of tangential velocity in boundary condition equation |

$\vec{t}$ vector tangent to surface

$\hat{t}$ unit vector tangent to surface

(u,v,w) components of perturbation velocity in coordinate system whose x-axis is aligned with freestream or uniform onset flow (DIP records G10, SF7 and FM14)

$\vec{U}_\infty$ uniform onset flow

$\vec{U}_o$ total onset flow

$\vec{U}_{loc}$ local onset flow (DIP record set N18)

$\vec{U}_{rot}$ rotational onset flow (DIP record set G6)

$\vec{v}$ perturbation velocity

$\vec{V}$ total velocity

$\vec{V}_\infty$ freestream velocity (in compressibility direction)

$V_{cr}$ critical speed

$V_m$ maximum speed (at vacuum condition)

$\vec{V}_*$ total velocity as used in pressure coefficient calculations, see equation (B.4.12)

[VIC] velocity influence coefficient matrix

$\vec{w}$ linearized perturbation mass flux

$\vec{W}$ total linearized mass flux

WAS wind axis system

(x,y,z) compressibility coordinate system

$(x_o,y_o,z_o)$ reference coordinate system

(x,y,z) scaled coordinate system

(x',y',z') a coordinate system for force and moment coefficients

## Greek Symbols

| | |
|---|---|
| $\alpha$ | angle of attack, rad |
| $\alpha_c$ | angle of attack defining compressibility direction, rad |
| $\beta$ | $= \lvert 1 - M_\infty^2 \rvert^{1/2}$ |
| $\beta$ | specified flow in boundary condition equation |
| $\beta_c$ | angle of sideslip defining compressibility direction, rad |
| $\gamma$ | ratio of specific heats of a gas |
| $\vec{\gamma}$ | surface vorticity vector, see equation (A.2.9) |
| $\Gamma$ | rotation matrix |
| $\Delta$ | difference between values on the upper and lower surfaces of a panel |
| $\Delta$ | difference between simulated and actual surfaces |
| $\Delta\vec{U}^*$ | $= \vec{V}_\infty - \vec{U}_\infty$ |
| $\Delta\vec{V}$ | incremental onset flow velocity |
| $\epsilon$ | user-defined tolerance distance for edge matching (DIP record G7) |
| $\theta$ | an Euler angle defining body axis system (DIP record FM3) |
| $\lambda$ | array of singularity parameters |
| $[\Lambda]$ | matrix of vectors of singularity parameters |
| $\mu$ | doublet strength at a point on a panel |
| $\mu_i$ | doublet strength at point on the ith edge of an abutment |
| $(\xi,\eta,\zeta)$ | panel coordinates |
| $\rho$ | density of fluid, $kg/m^3$ |
| $\rho_\infty$ | density of fluid in freestream, $kg/m^3$ |
| $\sigma$ | source strength at a point on a panel |
| $\Sigma$ | denotes summation |
| $\phi$ | perturbation potential, an Euler angle defining body axis system (DIP record FM3) |
| $\Psi$ | total potential |

| | |
|---|---|
| $\psi$ | an Euler angle defining body axis system (DIP record FM3) |
| $\bar{\Psi}$ | $= (x/s\beta^2, y, z)$ |
| $\vec{\omega}$ | rotational onset flow velocity |

Subscripts

| | |
|---|---|
| A | average of upper and lower surface values |
| c | compressibility, camber, closure |
| D | difference of upper and lower surface values |
| f | flap |
| i | input |
| L | lower surface value |
| n | normal direction |
| nm | normal mass flux |
| nv | normal velocity |
| p | potential |
| r | rotation |
| t | tangential direction, thickness |
| U | upper surface value |
| 1,2 | denotes first, second boundary condition equation |
| $\infty$ | denotes undisturbed flow |

Overscripts

| | |
|---|---|
| $\vec{\ }$ | denotes a vector |
| $\hat{\ }$ | denotes a unit vector |

Other Symbols

| | |
|---|---|
| $\partial$ | denotes partial differentiation |
| $\vec{\nabla}$ | gradient operator |
| $\tilde{\nabla}$ | compressible gradient operator, see section A.2 |
| { } | denotes a column vector |
| [ ] | denotes a matrix |
| $\iint$ | surface integral |
| << | very much less than |
| x | vector cross product operation |
| • | vector dot product operation |

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## A.0 Fundamental Aspects of Boundary Value Problems PAN AIR Can Solve

The fundamental ideas behind the method PAN AIR uses to solve boundary value problems are described in this appendix. First, some basic relations of fluid mechanics are summarized. Second, the properties of source and doublet panels are described. Third, the definition of a properly posed boundary value problem together with some examples of well and ill-posed boundary value problems are discussed.

### A.1 Prandtl-Glauert Equation

The perturbation velocity potential $\phi$ of the fluid motion satisfies a second-order linear partial differential equation called the Prandtl-Glauert equation

$$(1 - M_\infty^2)\ \phi_{xx} + \phi_{yy} + \phi_{zz} = 0 \qquad \text{(A.1.1)}$$

where $M_\infty$ is the Mach number of the freestream flow. PAN AIR solves the Prandtl-Glauert equation with appropriate boundary conditions for the fluid motion. The equation describes the steady, irrotational motion of a perfect, inviscid fluid. The equation is derived from the general relations of fluid motion by restriction to small perturbations from freestream flow and by exclusion of the range of transonic flow. For incompressible flow $M_\infty = 0$; the Prandtl-Glauert equation becomes Laplace's equation. For compressible flow the x-axis in the Prandtl-Glauert equation is termed the compressibility direction. (The compressibility direction is specified by the angles CALPHA and CBETA of record G5.) The Mach number can be less than or greater than one, corresponding to subsonic or supersonic flow.

The perturbation velocity of the fluid motion is the gradient of the perturbation velocity potential, that is,

$$\vec{v} = \vec{\nabla}\phi \qquad \text{(A.1.2)}$$

where $\vec{\nabla}$ is the gradient operator with components

$$\vec{\nabla} = \left( \frac{\partial}{\partial x}\ ,\ \frac{\partial}{\partial y}\ ,\ \frac{\partial}{\partial z} \right)$$

The total velocity of the fluid motion is the sum of the freestream and the perturbation velocities.

$$\vec{V} = \vec{V}_\infty + \vec{v} \qquad \text{(A.1.3)}$$

The freestream Mach number $M_\infty$ is the ratio of the freestream flow speed $\vec{V}_\infty$ and the freestream speed of sound.

The development of the Prandtl-Glauert equation from the basic relations of fluid mechanics is discussed in sections 2 and 3 of the Theory Document. The associated integral equation is discussed in appendices A and B of the Theory Document.

## A.2 Properties of Source and Doublet Panels

The properties of source and doublet panels are important in modeling flow fields. PAN AIR uses composite panels which have both source and doublet singularity distributions. The properties of the composite panels are a linear combination of the properties of source and doublet panels. The source and doublet singularities are related to the jump properties across a panel, which are important for understanding how each singularity is used to satisfy the imposed boundary conditions. (For standard aerodynamic analysis problems, that is, class 1 boundary conditions, the specification of the boundary condition equations is developed entirely by PAN AIR.) Each panel has two surfaces, the "upper" and "lower" surfaces, with the panel normal vector n pointing outward from the upper surface.

The source $\sigma$ and the doublet $\mu$ strengths of a panel are related to the jump properties across the panel.

$$\sigma = \hat{n} \cdot (\vec{W}_U - \vec{W}_L) \tag{A.2.1a}$$

$$\mu = \phi_U - \phi_L \tag{A.2.1b}$$

where $\hat{n} = (n_x, n_y, n_z)$ is the panel normal vector, $\vec{W}$ is the mass flux, and the subscripts U and L indicate the upper and lower surfaces of the panel.

The source strength can be expressed in terms of either the perturbation mass flux or the velocity potential. The total linearized mass flux is

$$\vec{W} = \vec{V}_\infty + \vec{w} \tag{A.2.2}$$

as discussed in section 5.4 of the Theory Document. The perturbation mass flux is

$$\vec{w} = \tilde{\nabla}\phi \tag{A.2.3}$$

where $\tilde{\nabla}$ is the compressible gradient operator with components

$$\tilde{\nabla} = \left(s\beta^2 \frac{\partial}{\partial x}, \frac{\partial}{\partial y}, \frac{\partial}{\partial z}\right)$$

where $s = \text{sign}\,(1 - M_\infty^2)$

$$\beta = \sqrt{s\,(1 - M_\infty^2)}$$

Thus the components of $\vec{w}$ and $\vec{v}$ are related as

$$(w_x , w_y , w_z ) = (s \beta^2 v_x , v_y , v_z) \qquad (A.2.4)$$

The panel source strength is expressed in terms of the perturbation mass flux and the potential by combining equations (A.2.1a), (A.2.2) and (A.2.3).

$$\sigma = \tilde{n} \cdot (\vec{w}_U - \vec{w}_L) \qquad (A.2.5a)$$

$$\sigma = \hat{n} \cdot \tilde{\nabla} \ (\phi_U - \phi_L) = \tilde{n} \cdot \vec{\nabla} \ (\phi_U - \phi_L) \qquad (A.2.5b)$$

where $\tilde{n} = (s \beta^2 n_x, n_y, n_z)$ is the panel conormal vector.

The relations between the jump properties across a panel and the source and doublet strengths on the panel are summarized in table A.1. The source strength on a panel is equal to the jump in the normal component of the mass flux (either perturbation or total) between the upper and lower surfaces of the panel. For the special case of incompressible flow the source strength is also equal to the jump in the normal velocity component. The doublet strength on the panel is equal to the jump in the velocity potential between the upper and lower surfaces. The preceding relations for the source and doublet strength are developed from the integral equation for the velocity potential in section 3 of the Theory Document.

| Jump | Source Panel | Doublet Panel |
|---|---|---|
| Normal Mass Flux, $\Delta w_n$ | $\sigma$ | 0 |
| Tangential Velocity, $\Delta \vec{v}_t$ | 0 | $\vec{\nabla}\mu$ |
| Potential, $\Delta \phi$ | 0 | $\mu$ |

Table A.1 - Values of the jumps between the upper and lower surfaces of composite panels (compressible flow)

The increment in potential due to a source density distribution over a panel of area $\delta S$, figure A.1, is

$$\delta\phi(P) = \frac{- \sigma(Q)}{4 \pi R(P,Q)} \ \delta S \qquad (A.2.6)$$

where $\sigma(Q)$ is the source density, $Q = (\xi, \eta, \zeta)$ is a point on the panel, $P = (x,y,z)$ is a point in space, and $R(P,Q)$ is the hyperbolic distance between points Q and P.

$$[R(P,Q)]^2 = (\xi - x)^2 + s\beta^2 [(\eta - y)^2 + (\zeta - z)^2] \qquad (A.2.7)$$

The jump properties of the source panel are shown in figure A.1. The normal component of the mass flux jumps across the panel, the jump being equal to the source strength on the panel by equation (A.2.1a). The velocity potential is continuous across a source panel. Since the velocity potential is continuous across the panel at all points on the panel, the tangential velocity component is also continuous across the panel.

The increment in potential due to a doublet density distribution over a panel of area $\delta S$, figure A.2, is

$$\delta\phi(P) = \mu(Q) \frac{\partial}{\partial n_Q} \left( \frac{1}{4 \pi R (P,Q)} \right) \delta S \qquad (A.2.8)$$

where $\mu(Q)$ is the doublet density. The jump properties of the doublet panel are shown in figure A.2. The potential jumps across the panel, the jump being equal to the doublet strength on the panel by equation (A.2.1b). The tangential velocity also jumps across the panel, the jump being equal to the gradient of the doublet strength on the panel. The normal component of the mass flux is continuous across the panel.

The doublet panels used in PAN AIR are equivalent to vortex panels. The equivalent surface vorticity is obtained from the doublet strength by the relation

$$\vec{\gamma} = \hat{n} \times \vec{\nabla} \mu \qquad (A.2.9)$$

where $\vec{\gamma}$ is the surface vorticity vector. Both $\vec{\gamma}$ and $\vec{\nabla}\mu$ are in the plane of the panel.

The properties of a vortex panel are shown in figure A.3. The jump properties of the vortex panel are the same as those of the equivalent doublet panel. The velocity potential is discontinuous across the panel, the jump being equal to the doublet strength. The tangential velocity is discontinuous across the panel, the jump being related to the surface vorticity by equation (A.2.9). In component form

$$(v_{x'})_U - (v_{x'})_L = \gamma_{y'} \qquad (A.2.10a)$$

$$(v_{y'})_U - (v_{y'})_L = - \gamma_{x'} \qquad (A.2.10b)$$

where x' and y' are orthogonal coordinates in the panel plane. The normal component of the mass flux is continuous across the vortex panel.

Since the surface vorticity is related to the derivatives of the doublet strength, a discontinuity in the doublet strength introduces line vortex terms (see appendix B.3 of the Theory Document). This is illustrated by a simple example. Consider a distribution of doublet strength in the x'y' plane whose strength is constant for positive values of x', that is,

$$\mu(x', y') = \begin{cases} 0 & x' \leq 0 \\ \mu_0 & x' > 0 \end{cases}$$

This doublet distribution gives the same flow field as a line vortex aligned with the positive y'-axis and having strength $\mu_0$. The doublet sheet is accordingly equivalent to this line vortex, with a cut introduced on the x'y' half-plane ($x' > 0$) to allow a discontinuity in the potential, equal to $\mu_0$ by equation (A.2.1b), across the half-plane. In a similar manner, a doublet panel with constant doublet strength is equivalent to a constant strength ring vortex located on the panel perimeter.

The composite panel of PAN AIR includes both the source and doublet panels. The jump conditions associated with the composite panel are simply a linear combination of those for the source and doublet panels.

## A.3 Well and Ill-Posed Boundary Value Problems

PAN AIR can solve only properly posed boundary value problems, so it behooves the pioneering user to understand what this means. The dictates thus imposed arise directly from the fundamental mathematical requirements (reference A.1) of the partial differential equation being solved and are in no way related to the numerics associated with PAN AIR. The key issues involved are the following.

### A.3.1 Domains, Boundaries and Surfaces

A "domain" is defined to be a region in space containing fluid. A "boundary" is defined to be a perimeter of a domain. The term "surface" is given a special meaning: a boundary has two surfaces either referred to as "inner" and "outer" if useful for physical interpretation or referred to as "upper" and "lower" which are specific designations in PAN AIR. The terminology for the two surfaces of a boundary is required since boundary conditions must be specified on both surfaces in most problems.

Each domain is completely circumscribed by a boundary. This simple statement can be somewhat difficult to comprehend for domains which extend to infinity. However, this is easily overcome by adopting the thinking that there always must exist a boundary at infinity. Figure A.4 gives an example containing two domains and two boundaries. Domain 1 is bounded completely (that is, "closed") by the boundary at infinity and the "outer" surface of the finite boundary. Domain 2 is bounded completely by the "inner" surface of the finite boundary.

Another classification of surfaces occurs in supersonic flow because the nature of the boundary value problem depends upon the surface inclination. Surface panels are classified as "superinclined" or "subinclined" if the panel is inclined ahead of or behind the Mach lines of the freestream flow, respectively. Examples are given in figure A.5. Equivalently the panel is superinclined or subinclined if the product $(\hat{n}\cdot\tilde{n})$ of the panel normal and conormal vectors is negative or positive, respectively (see section 5.2 of the Theory Document). If the panel is superinclined, no point on the panel lies in the downstream zone of influence of any other point on the panel. If the panel is subinclined, the more downstream points lie in the zone of influence of the more upstream points. The distinction between subinclined and superinclined panels is fundamental in formulating boundary value problems in supersonic flow. The standard application of superinclined panels is at an engine, either to seal off the inlet or to specify exhaust mass flow. Superinclined panels should be avoided in such applications as the blunt leading edge of a wing. However, if the leading edge is subsonic, the panels on the leading edge will be subinclined.

### A.3.2 Flow in a Domain

The flow in any one domain is governed entirely by boundary conditions applied on the surfaces which are "wetted" by the domain. In the example of figure A.4, the flow in domain 1 is governed entirely by boundary conditions applied on the boundary surface at infinity and on the outer surface of the finite boundary, these surfaces hereinafter being referred to as the boundary surfaces of domain 1. The flow in domain 2 is governed entirely by boundary conditions applied on the inner surface of the finite boundary. Note that the flows in each domain are completely isolated from one another in the sense that all boundary conditions affecting the flow in domain 1 do not influence the flow in domain 2, and vice versa.

Since flows in separate domains are completely independent of each other, it is essential that the PAN AIR user realize when domains are separate and when they are not in a given problem. A fairly common situation is shown in figure A.6. In figure A.6a a closed boundary is defined which separates domain 1 outside the boundary from domain 2 inside the boundary. In figure A.6b an open boundary is defined resulting in a single domain which includes the regions outside and inside the open boundary. A common example illustrating a practical encounter with these distinctions is the treatment of a wing tip. If the tip is closed by means of a paneled surface, then two domains are created and the flow about the exterior of the wing is completely isolated from that in the interior domain. But if the wing tip is left open, the "inside" of the wing becomes part of the external flow domain. Consequently, the boundary conditions on the inside surface will influence the external flow field, possibly in a significant and unrealistic manner.

#### A.3.2.1 Subsonic Case

In a subsonic flow, boundary conditions applied on any portion of the boundary surfaces wetted by a domain influence the flow throughout the entire domain.

A.3.2.2 Supersonic Case

In a supersonic flow, boundary conditions applied on any portion of a boundary surface wetted by a domain influence the flow only in a region bounded by the Mach cone envelope opening downstream from that portion of the boundary surface.

A.3.3 Boundary Conditions

A.3.3.1 Subsonic Case

In the subsonic case, boundary conditions governing the flow in any domain must be applied on every part of every boundary surface wetted by the domain. There can be no exceptions; there can not exist a part of the boundary surface wetted by the domain that does not have an associated boundary condition.

Furthermore, only certain types of boundary conditions are allowed, namely those of the form

$$a\,(\vec{w}\cdot\hat{n}) + c\,\phi + d\,\frac{\partial\phi}{\partial t} + e\,\frac{\partial\phi}{\partial n} = b \qquad \text{(A.3.1)}$$

where a, b, c, d and e are specified. PAN AIR allows the user to specify the general boundary condition of equation (A.3.1).

In the case where c=d=e=0, this reduces to the classical "Neumann" boundary condition allowing the specification of the normal mass flux, that is,

$$\vec{w}\cdot\hat{n} = \frac{b}{a} \qquad \text{(A.3.2)}$$

(In PAN AIR normal mass flux boundary conditions are usually used in preference to normal velocity boundary conditions. The two conditions become equivalent in incompressible flow.)

In the case where a=d=e=0, this reduces to the classical "Dirichlet" boundary condition allowing the specification of $\phi$, that is,

$$\phi = \frac{b}{c} \qquad \text{(A.3.3)}$$

In the case where a=c=e=0, this reduces to a design-type boundary condition allowing the specification of $\frac{\partial\phi}{\partial t}$, a tangential velocity component.

In all cases with subsonic flow, only one such boundary condition is permitted on any part of a boundary surface. It is never permissible to impose more than one boundary condition on the same part of a boundary surface. Note, however, that we are defining the boundary surface as that wetted by the domain. Thus, in the example of figure A.4, the finite boundary contains two surfaces, its "inner" and "outer" surface. One is allowed and

required to apply one boundary condition on the outer surface to control the flow in domain 1, and one is allowed and required to apply one boundary condition on the inner surface to control the flow in domain 2. These two boundary conditions are to be thought of as completely independent.

In PAN AIR the boundary condition required to be applied at any and all boundary surfaces located at infinity is dealt with automatically through specification of the free stream conditions and/or the angles of attack and sideslip, which are controlled directly by the conditions at infinity. The user need not be further concerned about the boundary conditions at infinity.

### A.3.3.2 Supersonic Case

In the supersonic case the rules are different. Here we have the possibilities of subinclined boundary surfaces or superinclined boundary surfaces. (PAN AIR does not permit the use of boundary surfaces inclined at exactly the Mach angle.)

(1) Subinclined Surfaces. For these the rules are the same as for subsonic flow, namely there must be one and only one boundary condition on every subinclined part of a boundary surface wetted by a domain. The permissible choices are the same as for subsonic flow, that is, those listed in equation (A.3.1).

(2) Superinclined Surfaces. The two basic rules for superinclined surfaces are shown in figure A.7. The first rule is that no boundary conditions are permitted on any portion of the upstream surface of a superinclined boundary. (Any conditions on this surface would have no effect on the upstream flow field.) The second rule is that two independent boundary conditions must be imposed on each and every portion of the downstream surface of a superinclined boundary. The permissible choices for the two boundary conditions are those listed in equation (A.3.1). Application of these two rules is shown in figure A.8. Figure A.8a is an example of flow impinging on a superinclined nacelle inlet. Since no boundary condition can be imposed on the upstream surface, no condition can be used to specify the nacelle inlet flow. Figure A.8b is an example of flow exiting from a nacelle outlet. Since two boundary conditions can and must be imposed on the downstream surface, one condition can be used to specify the nacelle outlet flow.

## A.3.4 Special Rules

There are a few special rules which are exceptions to those specified in section A.3.3. They are the following.

### A.3.4.1 Domains not Wetting a Boundary Surface at Infinity

The simplest example of this is domain 2 of figure A.4, which is completely enveloped by a finite boundary. Another example is that of a domain bounded by a tubular surface extending to infinity as sketched in

figure A.9. (This domain falls loosely within the definition of "not wetting a boundary surface at infinity" in the sense that the angle subtended by a cross-section of the tube is zero at infinity.) This example is commonly encountered in the modeling of propulsion system exhaust plumes. In these cases, the following special rules apply.

(1) Subsonic Flow - Rule 1. Neumann boundary conditions applied everywhere on the boundary surface wetted by the (finite) domain are illegal (for example, equation (A.3.2) applied everywhere on the surface). A physical rationale underlying this rule is readily apparent in the example of figure A.4, whereby its violation would enable the boundary conditions to command a net flux of mass into or out of the domain 2 of finite size, which is clearly not physically possible. This rationale is somewhat obscure in the example of figure A.9, but the rule is nevertheless valid. If the user violates this special rule with PAN AIR his run will blow, usually with a singular matrix. (Note that this is an inherent problem, so that the user can not avoid the problem by insuring, even to extreme accuracy, that the net mass flux flowing from the surface is zero.)

This rule does not apply if the domain extends to infinity with a nonzero subtended angle. In figure A.4, for example, mass flux boundary conditions can be specified on the outer surface of the finite boundary. The resulting boundary value problem in the infinite domain 1 will be properly posed. The net mass flux out of the surface wetted by the infinite domain need not be zero. However, in figure A.9 the domain within the tube extends to infinity with zero subtended angle and hence mass flux boundary conditions applied everywhere on the surface wetted by this domain are illegal.

The examples of figure A.6 show how this rule requires the user to realize what domains have been defined when he specifies the configuration boundaries. With the closed boundary of figure A.6a, domain 2 is of finite size, so that it is illegal to specify mass flux boundary conditions on the inside surface of the boundary. With the open boundary of figure A.6b, there is no domain of finite size. Thus it is legal to specify mass flux boundary conditions on the inside surface of the boundary. Conversely however, any boundary conditions specified on that surface will influence the "external" flow field, as discussed previously.

(2) Subsonic Flow - Rule 2. A Dirichlet boundary condition, equation (A.3.3), must be used at least at one point on the surface of an interior domain such as domain 2 of figure A.4 and the inside of the tube of figure A.9. If this is not done, the absolute level of the velocity potential within the domain will be indeterminate. When using the PAN AIR class 1 boundary conditions for a thick configuration, for example, the perturbation velocity potential is set to zero on the surface wetted by the finite domain.

(3) Supersonic Flow - Rules. This flow regime is less well understood at the present time. However, recent work seems to be leading toward the suggestion that the boundary value problem is always well-posed when the downstream end of a domain contains some region of superinclined boundary surface or extends to infinity. Also, computational experience indicates that useful, physically valid solutions are usually obtained with the class 1 boundary conditions, but the fundamental mathematical justification for the validity of this boundary value formulation remains to be proved for supersonic flow. Indeed, there are indications that if nonsmooth or nonzero values of the perturbation potential are prescribed, a true (in a mathematical sense) solution may not exist.

### A.3.4.2 Design Type Boundary Conditions

The specification of $\frac{\partial \phi}{\partial t} = f(s,t)$ as a boundary condition, where s,t refer to local coordinates on a surface, does not yield, by itself, a unique solution. This can be seen by integrating this expression to yield

$$\phi(s,t) = \int \frac{\partial \phi}{\partial t} \, dt + g(s) \qquad \text{(A.3.4)}$$

where g(s) is any arbitrary function of s. Equation (A.3.4) is the classic Dirichlet boundary condition and thus constitutes a well-posed boundary condition. The problem is that g(s) is indeterminate. Therefore, additional boundary conditions must be formulated to establish g(s).

These conditions are obtained from physical features of the flow and are handled automatically for the user in PAN AIR. In the case of a thin lifting wing design, g(s) may be viewed as an indeterminacy in the level of the potential as a function of the spanwise coordinate (corresponding to s). PAN AIR selects that solution which renders the potential jump across the wing at its leading edge to be zero, which is the physically correct condition. In other cases involving thickness design, the PAN AIR input allows the user to specify a closure condition, which renders g(s) determinate.

### A.3.4.3 Mixed Type Boundary Conditions

PAN AIR is sufficiently general to permit a user to input mixed boundary conditions of the form of equation (A.3.1). However, existence and uniqueness issues associated with special cases which may arise have not been examined at this time, so the user should proceed with caution and an inquisitive mind.

## A.3.5 Connectivity, Wakes and Kutta Conditions

The inquisitive reader will find the subject of connectivity discussed in a variety of texts (references A.2 and A.3). Indeed, the advanced user may find it instructive to read the literature on the subject, but for almost all practical purposes the PAN AIR user need only model his problem using a reasonable degree of physical insight in the treatment of wakes.

The textbooks state that a multiply-connected domain must be rendered singly-connected by the insertion of appropriate "cuts" or "barriers" in space before it can be solved as a properly posed boundary value problem. An example of this is shown in figure A.10 for the case of a two-dimensional configuration and flow field. In figure A.10a the exterior domain is doubly-connected due to the isolated, finite boundary. In figure A.10b a cut representing a doublet sheet has been added which connects the isolated boundary with that at infinity. The exterior region is now singly-connected. (In practice a panel model of a doublet sheet can not and need not extend to infinity.) In aerodynamics problems these "cuts" are invariably doublet sheets representing physical wakes emanating from physical boundaries in the

presence of Kutta conditions. If the PAN AIR user selects the presence or absence of wakes and Kutta conditions by following physical observation and his aerodynamics training, PAN AIR will invariably relieve him of further worries of mathematical connectivity. In adding the physically proper wakes and Kutta conditions to his physical problem, he will have added the "cuts" or "barriers" discussed by the mathematician. Also, PAN AIR will automatically impose the proper boundary condition at the abutment of the trailing edge of the physical (non-wake) boundary and the wake. With a subsonic trailing edge, the Kutta condition is applied. With a supersonic trailing edge, the flows on the upper and lower surfaces of the physical boundary are independent.

For those who have studied the texts, we report that PAN AIR will produce a unique solution to a problem with a multiply-connected domain. The solution produced will be the one corresponding to continuity of the velocity potential across any cut or cuts the user would otherwise have added. A simple example illustrating this would be a two dimensional airfoil in the absence of a wake. In such a case, there is no mechanism for the user to apply a Kutta condition (because we have purposefully omitted the doublet wake in order to create a doubly-connected domain) and PAN AIR would produce the nonlifting flow solution about the airfoil irregardless of its angles of attack and camber.

### A.3.6 Integral Equation Considerations

PAN AIR solves the Prandtl-Glauert equation by means of an integral equation formulation (see appendix B of the Theory Document). One consequence is that solutions are produced in all space, encompassing every domain. In the typical engineering problem only certain of the domains are of physical interest. For example, in the analysis of flow over a thick wing or body, only the domain extending from the configuration boundaries to infinity is of physical interest. Nevertheless, PAN AIR will produce solutions in all space, which in this example will include a flow solution in the nonphysical domain corresponding to the physical interior of the thick wing or body.

The primary reason that the PAN AIR user must be concerned with flows in nonphysical domains is that the mathematics embodied in PAN AIR require that all boundary value problems governing flows in the nonphysical domains be well posed, just as is required in the physical domains. Thus, the rules and exceptions set forth in the preceding paragraphs apply equally to physical and nonphysical domains.

Having learned that attention must be paid to the boundary value problem formulations in nonphysical domains, the user must next be provided with means enabling him to determine the character of the boundary value problem in nonphysical domains and to modify or fix it if required to render it properly posed. For this we list two possibilities. (The following discussion covers the cases of subsonic flow and supersonic flow without superinclined panels.)

1. Direct Specification of Boundary Conditions on All Boundaries of All Domains. This option is always available. The user is free to specify whatever boundary conditions he desires on surfaces wetted by nonphysical domains, subject to the rules listed heretofore. In so doing he would probably try to select boundary conditions that produced smooth singularity

strength variations on the surfaces so as to enhance the overall numerical accuracy of the solution. In practice this option is not recommended because it is computationally expensive. It requires the use of sources and doublets of unknown strengths on every boundary and this leads to unnecessarily large matrices to be solved.

2. Selection of One Surface Singularity Type So as to Produce Proper Boundary Value Formulations in All Domains. This is the option used by PAN AIR in most of the standard classes of problems. Whenever a boundary exists between two domains, it is necessary to specify boundary conditions associated with each surface (that is, two conditions for the boundary, one applying to each surface), or to specify something which is equivalent. Many different options are available which are equivalent. For instance, it is permissible to specify one condition on the average flow (the average of the flows on the two surfaces of the boundary) and another on the difference between these flows. Alternately, it is permissible to substitute the direct specification of the strength of either the sources or the doublets for one of the two surface boundary conditions. This latter option leaves only one flow boundary condition to be applied. It is usually applied on only one surface of the boundary.

This latter option, namely specification of one flow boundary condition on one surface, plus specification of one singularity strength, is the option most commonly used in PAN AIR. It is computationally efficient because the size of the matrix equation to be solved is reduced since only one type of singularity strength remains to be determined from the flow boundary condition. One example of this type of treatment is the class 1 boundary condition (subclasses 1 and 2) wherein the source strength is specified and then the value of the velocity potential on one surface (that wetted by the nonphysical flow) is specified as the flow boundary condition. Other combinations are also permissible.

When using such modeling with flow boundary conditions imposed on only one surface, it is necessary to have a means for deciphering what effective or implied flow boundary condition applies on the other surface of the boundary. This is needed to be able to determine the character of the boundary value problem governing the domain that lies across the boundary so that it can be examined to ensure that it is properly posed. Many examples can be constructed wherein the boundary value problem thus imposed on adjacent domains is not well-posed. When this happens PAN AIR will blow and leave the user scratching his head over the cause of the problem.

The means by which a user deciphers the character of the boundary value problems on both surfaces of a boundary is through the jump conditions associated with source and doublet sheets, which are:

Source Sheet:

- velocity potential is continuous across the sheet
- tangential velocity component is continuous
- normal mass flux component is discontinuous, the magnitude of the discontinuity being equal to the strength of the source sheet

Doublet Sheet:

- velocity potential is discontinuous, the magnitude of the discontinuity being equal to the strength of the doublet sheet
- tangential velocity component is discontinuous, the magnitude of the discontinuity being equal to the gradient in doublet strength
- normal component of mass flux is continuous across the sheet.

Thus, consider the two examples illustrated in figure A.11. In the example of figure A.11a we suppose that the source strength has been specified on the boundary and that a flow boundary condition (of any permissible type) has been imposed on the surface wetted by domain 1. The character of the boundary value problem in domain 1 is governed by the type of flow boundary condition used and is not an issue. The question is, what is the character of the implied boundary condition on the surface wetted by domain 2. The answer can be found as follows by examining the jump conditions. First, the flow in domain 1 is completely determinate from its boundary conditions: the velocity potential and the normal and tangential velocity components on the surface of the boundary wetted by domain 1 are thus determinate. Examining next the jump conditions, we note that the jump in the normal component of mass flux across the boundary is completely determinate, being equal to the strength of the source sheet, which is given; the doublet sheet induces no jump in the normal component of the mass flux. Hence, the boundary conditions of figure A.11a are equivalent to the specification of the normal component of mass flux on the surface wetted by domain 2. We thus learn the character of the boundary value problem in domain 2 to be of Neumann type. In summary, specification of a flow boundary condition on one surface plus specification of the source strength on the boundary is equivalent to specification of a flow boundary condition on one surface of the boundary and a Neumann-type boundary condition on the other surface.

Referring now to figure A.11b we suppose that the doublet strength has been specified on the boundary and that a flow boundary condition (of any permissible type) has been imposed on the surface wetted by domain 1. Again the flow in domain 1 is completely determinate from its boundary conditions. Examining next the jump conditions, we note that the jump in velocity potential across the boundary is completely known from the given information, hence the magnitude of the velocity potential on the surface of the boundary wetted by domain 2 is determinate. Hence we learn that the boundary value problem in domain 2 is of Dirichlet type (velocity potential specified).

The type of reasoning outlined above enables the PAN AIR user to ascertain the character of the boundary value problem in domains where boundary conditions are not directly specified, and therefore to determine whether they are proper in the sense of satisfying the rules listed heretofore. A simple example is the class 1 boundary condition for flow about an object such as a thick wing or body. The velocity potential is fixed on the surface wetted by the nonphysical domain forming the interior of the object, and the source strength on the boundary is fixed. First it is observed that the boundary value problem in the nonphysical domain is of Dirichlet type and is thus properly posed, satisfying the rules set forth in section A.3.3 and the exceptions listed in section A.3.4. Turning next to the physical domain

extending from the boundary to infinity, we observe from the jump condition reasoning discussed above that the equivalent boundary conditions on the surface wetted by the physical domain are of Neumann type. Referring to the rules, we find this to be permissible. Thus the boundary value problems in all domains are properly posed and hence PAN AIR should produce a solution.

Let us consider next the example of figure A.12. Here the user is interested in the physical flow in the exterior domain 1 and has chosen to specify that the mass flux be parallel to the object's boundary by imposing the condition that $\vec{W} \cdot \hat{n} = 0$ on the surface wetted by domain 1. He has also elected to fix the source strength on the boundary to some specified value (perhaps zero, leaving only doublets on the surface, although the choice is unimportant for this example). PAN AIR will allow him to set up this problem, but the program will blow if he tries to run it!

To learn why, we first examine the character of the boundary value problem in domain 1. It is of Neumann type, satisfies all rules and is therefore permissible. Turning now to the nonphysical domain 2, we ascertain from the jump conditions that the equivalent boundary conditions on the surface wetted by domain 2 are also of Neumann type. This is the cause of the problem, since it violates rules 1 and 2 (subsonic flow) listed in section A.3.4.

When a PAN AIR user observes such problems, he must change the problem formulation. He usually has several choices. In the present example he could choose to specify the doublet strength on the boundary instead of the source strength. This causes the boundary value problem in the nonphysical domain to be of Dirichlet type, which is satisfactory. Or, he could insert a small source panel anywhere in domain 2 and accompany it with a boundary condition setting the potential to any arbitrary number. This effectively introduces another surface within the domain on which a Dirichlet boundary condition is imposed, thereby satisfying the restrictions listed in section A.3.4.

Another example that most PAN AIR users eventually encounter occurs in the modeling of exhaust plumes from propulsion devices. In the model (and subsonic flow) of figure A.13a there are two domains. The boundary conditions governing the flow in domain 1 are well-posed, comprising Neumann conditions on the impermeable surfaces and a Kutta condition at the trailing edge accompanied by an appropriate doublet wake. The reader can use the prior discussion and examples to ascertain the validity of the modeling in domain 2, this being dependent on the particular boundary conditions applied, which have not been stated in this example.

The model of figure A.13b is one frequently used when the user desires to control the inflow and outflow from the nacelle. Again the flow in domain 1 is well-posed, and in domain 2 is dependent on information which has not been stated. The domain that frequently causes trouble with inexperienced users is domain 3. Here, part of the domain boundary surface is formed by the trailing doublet sheet, which from the jump conditions is equivalent to specification of a Neumann type of boundary condition. (This problem is of Neumann type since the source strength on the doublet sheet is zero which, together with the well-posed problem in domain 2, results in a normal mass flux boundary condition on the surface wetted by domain 2. See the previous discussion of figure A.11a as an example of a boundary with specified source strength.) Another part of the boundary surface is labeled "impermeable", implying that the user specifies Neumann conditions here also. The difficult part of the

boundary surface is that labeled with a question mark. The typical error made by an inexperienced user is to specify Neumann boundary conditions on this surface (or to impose a boundary condition upstream in domain 2 together with a specified source strength, which is equivalent). His motivation is usually to attempt control of the mass flow exiting from the nacelle. The result is invariably the same, namely a blown run! The reason is that this modeling violates both rules listed under section A.3.4.

To meet these rules the user must (1) find a way to avoid the use of Neumann conditions everywhere on the boundary surface, and (2) find a way to set the global value of the potential within domain 3. This is most easily done by selecting a Dirichlet boundary condition for the surface having the question mark, using any arbitrary value for the potential to be specified. The flow solution will be independent of the magnitude selected for the potential. (Differing magnitudes are achieved by the appearance of different constant values of doublet strength added to the entire boundary of domain 3. Since a constant strength doublet sheet having no perimeter edge induces no velocity, the flow field will be independent of the magnitude of this constant). With this model the amount of fluid exiting from the nacelle will be determined from the overall flow characteristics about the nacelle which in turn are dependent on the shape and location of the wake networks. This is as it should be, since in the presence of Kutta conditions surrounding the exit one is not free to specify independently the exiting flow.

### A.3.7 Integral and Matrix Equations

The Prandtl-Glauert differential equation is converted to an integral equation in order to apply the panel method. The development of the appropriate integral equation is discussed in appendix B of the Theory Document. The solution of the Prandtl-Glauert equation or the equivalent integral equation requires a set of boundary conditions. The general boundary condition equation (A.3.1) specifies a linear combination of the normal mass flux, velocity potential, tangential velocity and normal velocity at points on each panel. Given the general functional dependence of the source and doublet distributions which are used in PAN AIR, the boundary conditions are expressed as a linear combination of unknown singularity parameters. The collection of all boundary conditions forms the matrix equation

$$[AIC] \quad \{\lambda\} \quad = \quad \{b\} \qquad (A.3.5)$$

where [AIC] is the aerodynamic influence coefficient matrix, $\{\lambda\}$ is the array of unknown singularity parameters and $\{b\}$ is the constraint array. The solution of the flow problem requires that the number of boundary condition equations be equal to the number of unknown singularity parameters, or equivalently that the AIC be a square, non-singular matrix. Equation (A.3.5) can then be solved for the unknown singularity parameters. The potential and velocity can then be determined, which determine the flow field satisfying the Prandtl-Glauert equation and the boundary conditions on the boundary surfaces.

### A.3.8 Ill-Conditioned Problems

Although problems are mathematically classified as either well-posed or ill-posed, the computer implementation of a problem solution introduces the additional catagory of ill-conditioned problems. These are problems which are in theory well-posed but are so close to being ill-posed that the computer can not effectively solve the problem. Equivalently, the aerodynamic influence coefficient matrix is ill-conditioned. However since the aerodynamic influence coefficient matrix is not singular, the program may operate without apparent difficulty, but the results could be meaningless.

The standard example of an ill-conditioned problem is one on the border line between well-posed and ill-posed problems. Consider the example of figure A.6, showing open and closed boundaries. If the boundary is closed by a panel spanning A-B as in figure A.6a and Neumann boundary conditions are imposed on the interior surface, then the problem is ill-posed. As a result, the AIC matrix will be singular and the solution will fail. But if the boundary is not closed, then with Neumann boundary conditions on the same surface, the problem is well-posed and can in principle be solved. However if the distance between A and B in the boundary becomes very small, the AIC matrix will be almost singular and therefore ill-conditioned. Thus although the problem is in theory well-posed, the computer solution could be meaningless. (In physical terms the total specified normal mass flux on the interior surface must be balanced by an outflow, possibly extremely large, through A-B.) A similar situation is the ill-posed Neumann problem in a domain enclosed by a wake which extends to infinity, figure A.9, for example. In practice a panel model of such a wake must have finite length, resulting in a well-posed problem. However if the wake is long, the AIC matrix will be almost singular and thus ill-conditioned. To avoid these situations, the user should not impose Neumann boundary conditions on closed or almost-closed boundaries. (Also, PAN AIR has automatic abutment and gap-filling panel features which can eliminate small holes in a boundary.)

Another type of ill-conditioned problem occurs through purely geometric considerations. There is a basic rule that two panel control points can not be in the same position since this causes a singular AIC matrix. (This is true in PAN AIR except for network edge control points, which receive special treatment.) If two control points are very close, but not coincident, the AIC can become ill-conditioned. The most common cause of this is the reflection of a network across one or two planes of symmetry, since the user may not realize that a particular network is being reflected. (In PAN AIR the reflection of networks in a plane of symmetry can be deleted either automatically by the program or directly by the user.)

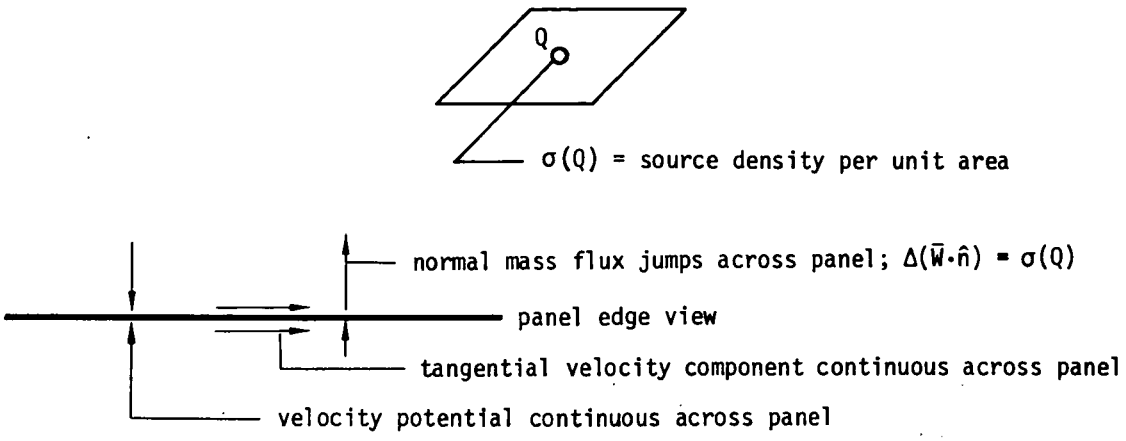



Figure A.1 - Source panel and its properties

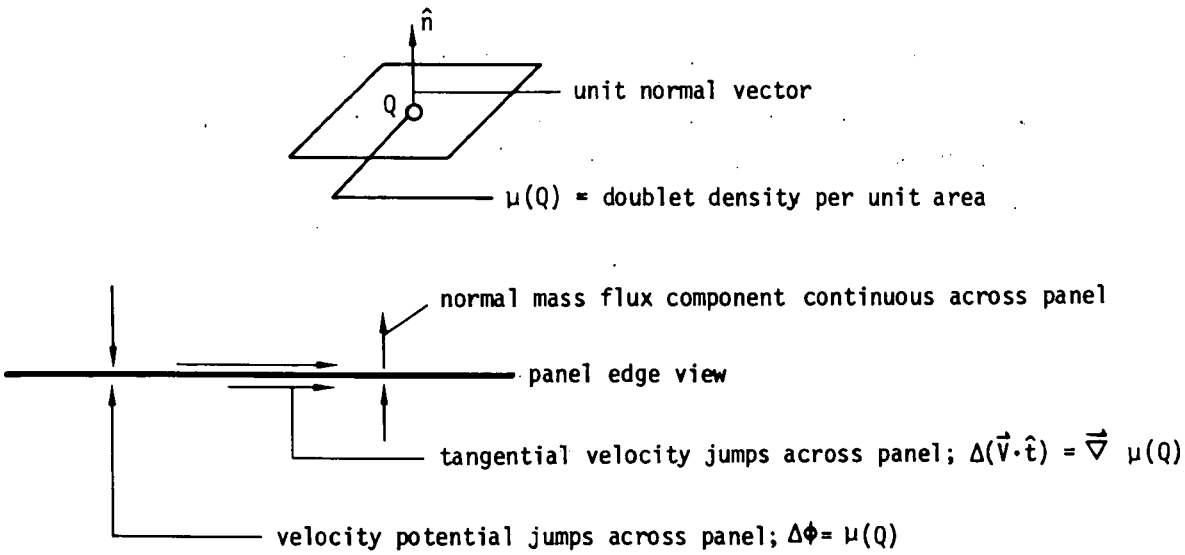
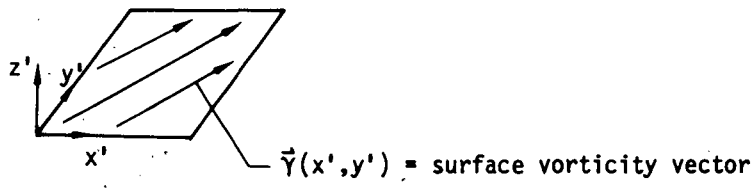



Figure A.2 - Doublet panel and its properties




- velocity potential is discontinuous across sheet
- tangential velocity jumps across sheet
- normal mass flux component $W_{z'}$ is continuous across sheet
- a continuous doublet sheet of strength $\mu(x,y)$ is exactly the same as a vortex sheet of strength $\vec{\gamma}(x,y) = \hat{n} \times \vec{\nabla}\mu(x,y)$

Figure A.3 - Equivalence of doublet and vortex sheets

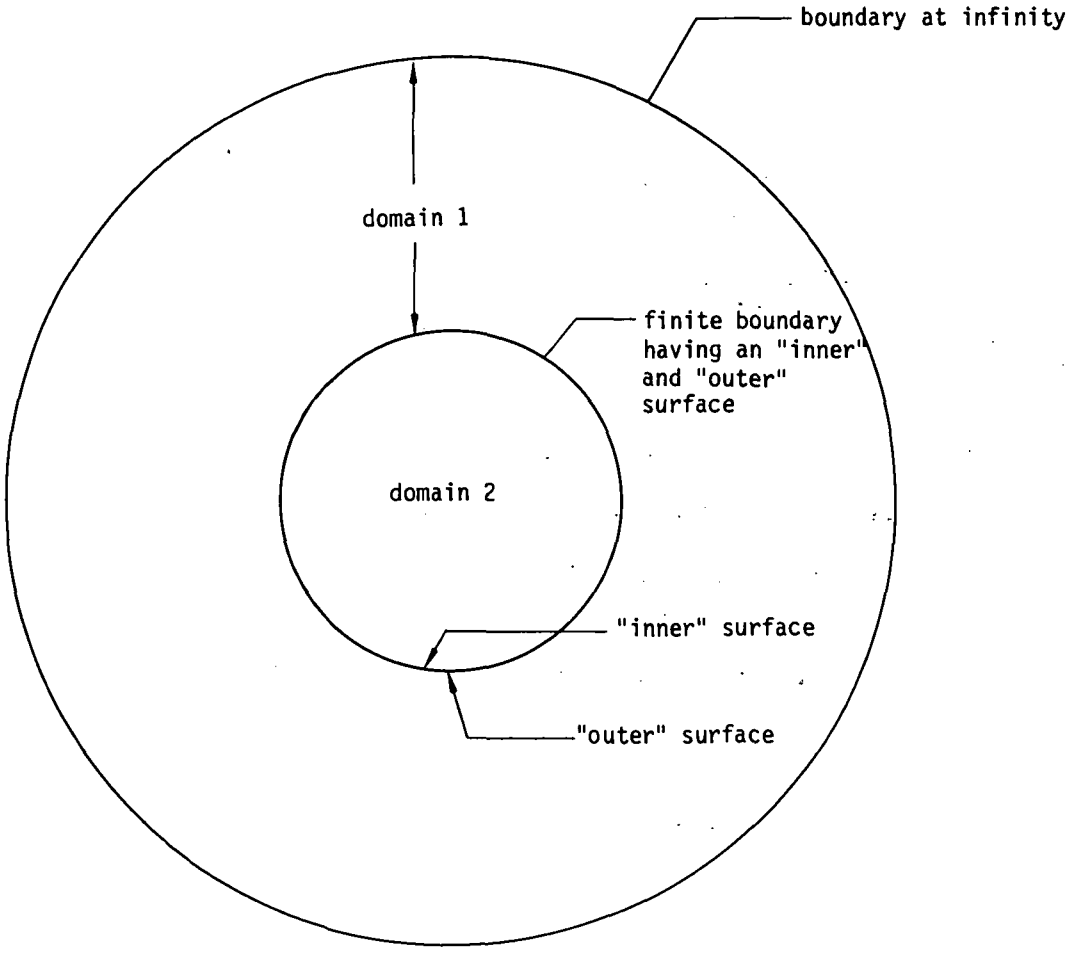



Figure A.4-Three dimensional field containing two domains

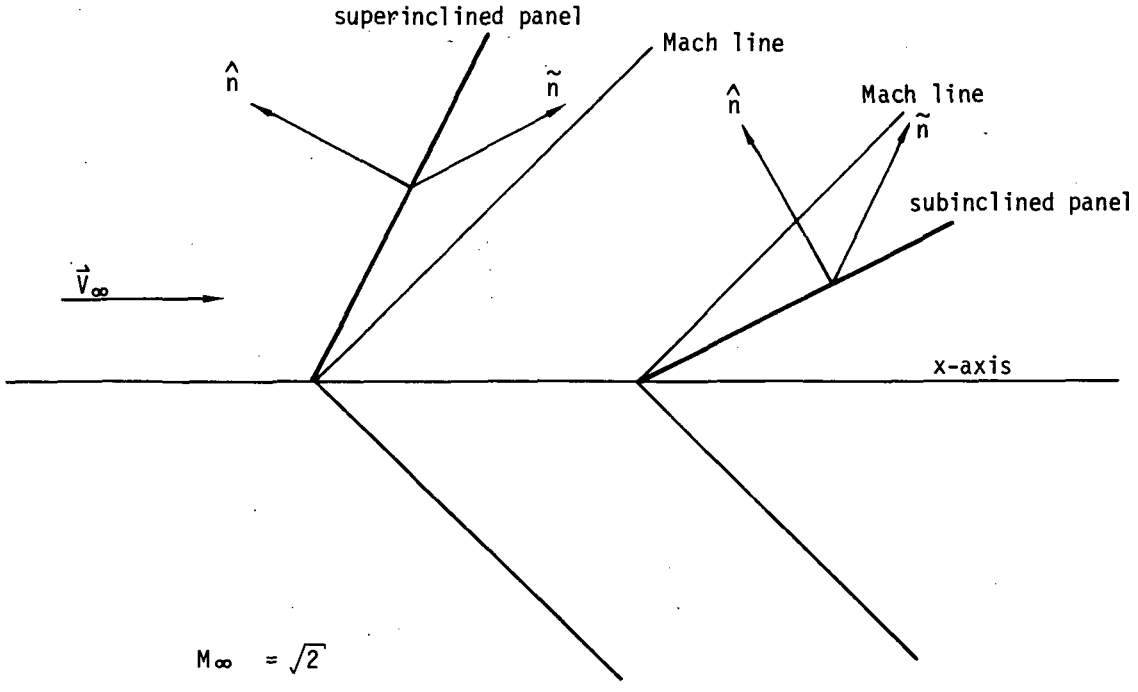
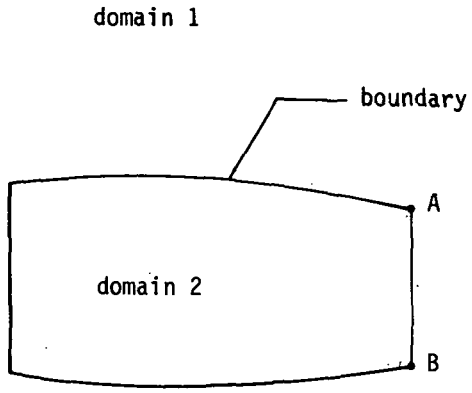
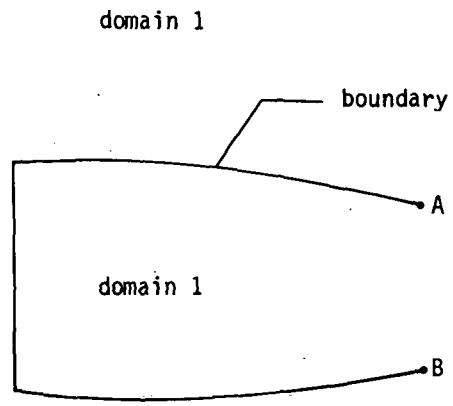



Figure A.5-Examples of subinclined and superinclined panels




a) Closed boundary, two domains




b) Open boundary

Figure A.6-Examples of closed and open boundaries

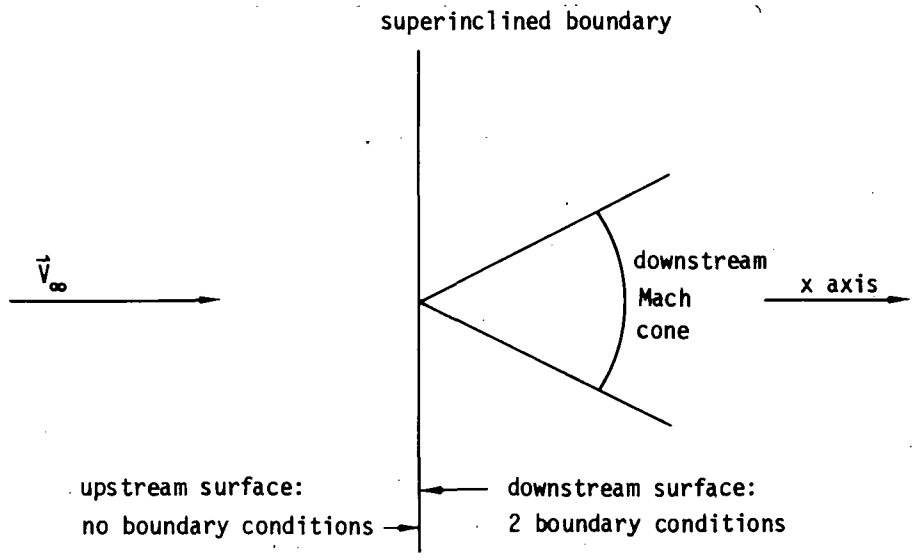
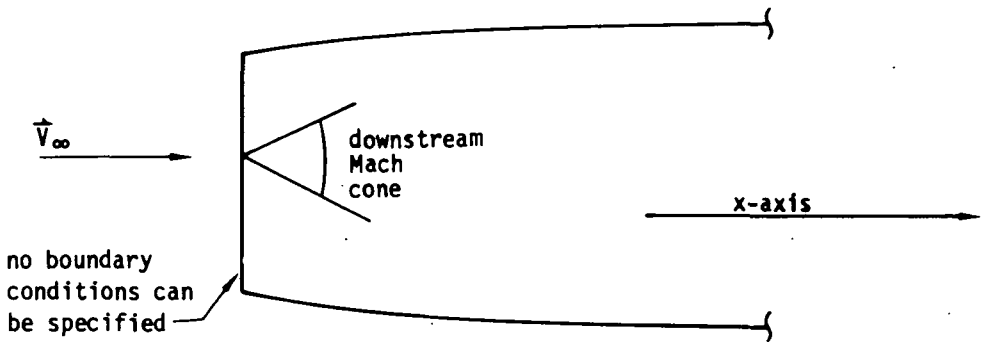
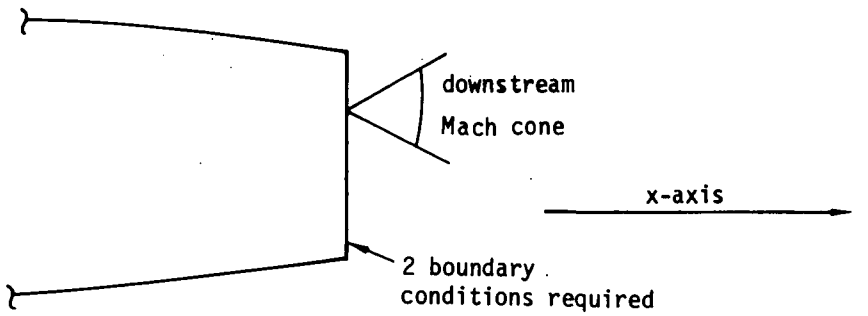



Figure A.7 - Boundary conditions required on surfaces of superinclined boundary




a) nacelle inlet




b) nacelle outlet

Figure A.8 - Two applications of superinclined networks

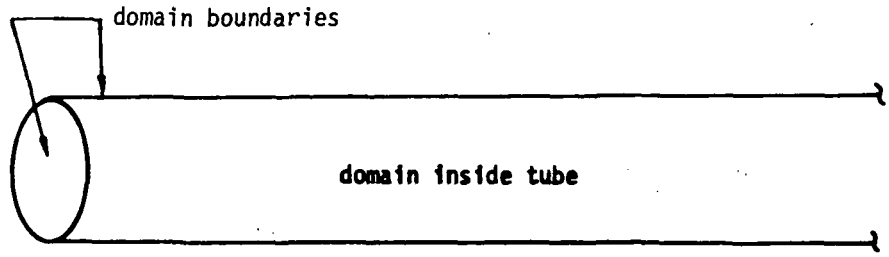
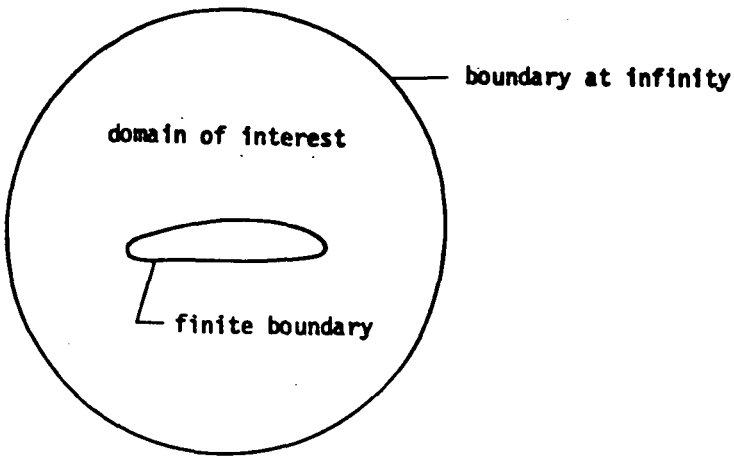
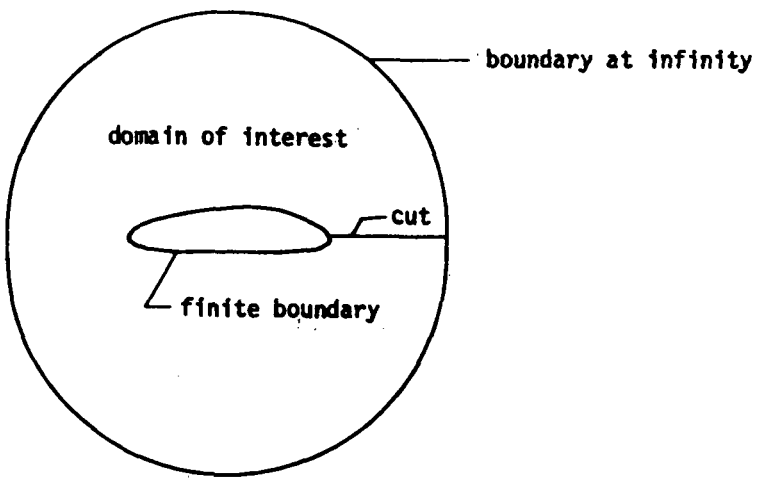



Figure A.9 - Tubular domain




a) doubly-connected domain




b) singly-connected domain

Figure A.10 - Examples of doubly-connected and singly-connected domains

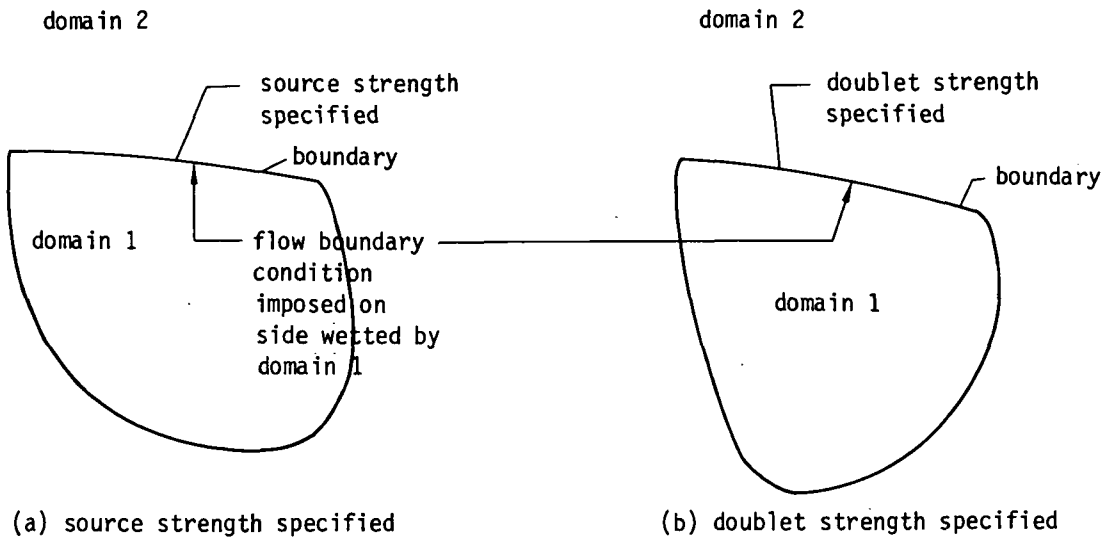



Figure A.11 - Boundary condition transfer across a boundary

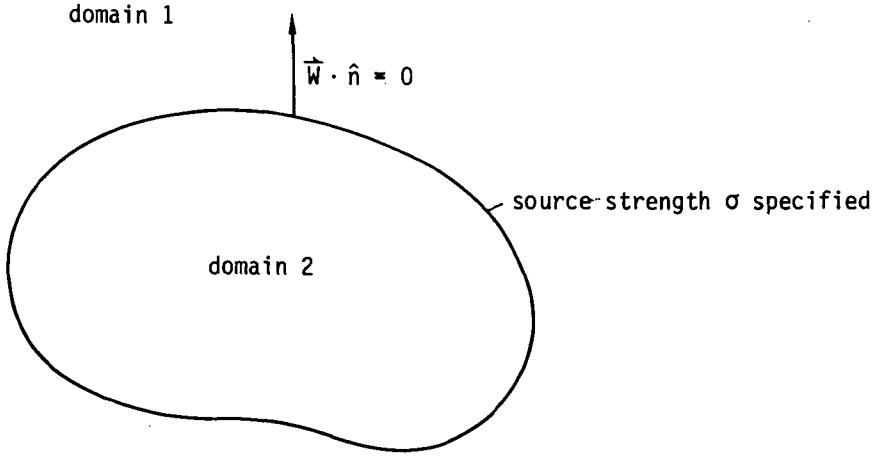
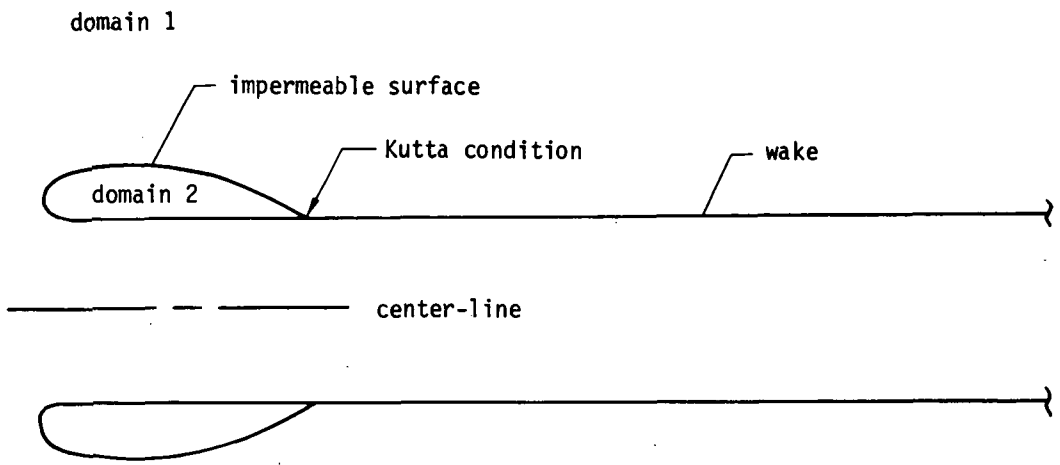
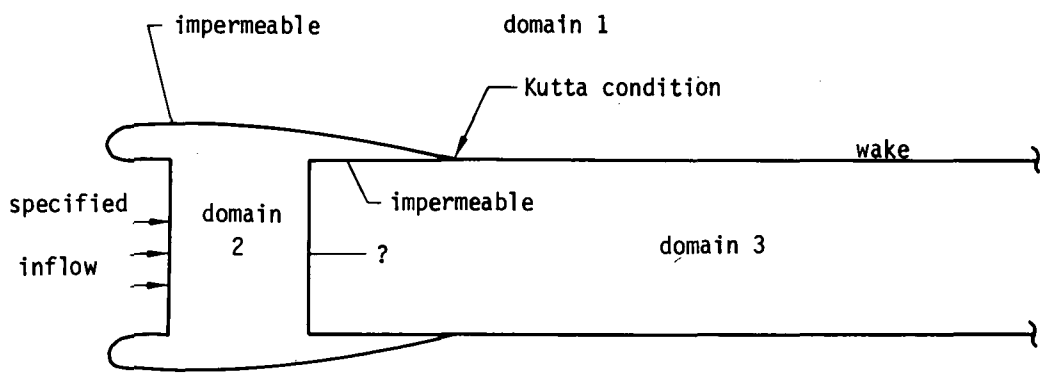



Figure A.12 - Example of an improper formulation




(a) flow nacelle




(b) nacelle with controlled inflow and outflow

Figure A.13 - Nacelle modelling in subsonic flow

## B.0 *Configuration and Flow Modeling in PAN AIR*

The modeling of physical configurations and fluid flow fields in PAN AIR is described in this appendix. First, the considerations involved in using networks and panels to model configuration and wake boundaries are discussed. Second, some general considerations involving coordinate systems, onset flows, and both configuration and flow symmetries are discussed. Third, the boundary condition equations are described. Finally, the flow field calculations available in PAN AIR are described.

## B.1 Configuration and Wake Modeling

The basic considerations involved in modeling configuration and wake boundaries are discussed in this section. The properties and restrictions on the definition of panels, networks and configurations are described. Some guidelines for the selection of panels and networks are also described.

### B.1.1 Basic Configuration Elements - Networks and Panels

The boundaries of both the physical and the wake configurations are defined by user-specified networks. In PAN AIR the number of boundary conditions on each network coincides with the number of assigned singularity parameters. This property together with automatic network edge matching conditions produces the logical independence of each network, that is, for each network the number of boundary condition equations equals the number of unknown singularity parameters.

The division of the configuration into networks is fairly arbitrary, but has certain restrictions. First, a network generally should correspond to a physically meaningful part of the total configuration. Examples of this are control surfaces, distinct parts of the wing, separate wake surfaces, and so forth. An example of the breakdown of a configuration into networks is shown in figure 2.1. Second, physically meaningful breaks in configurations must correspond to network edges. For example, significant slope discontinuities in a boundary must occur at network edges. Third, networks can abut only at their edges. Finally, since a network is the basic unit for the definition of input data, a good choice of the networks can simplify the input data. For example, it is convenient if a network has only one class of boundary condition equations, one type of local onset flow, one type of specified flow, and so forth.

The networks are combined to form user-specified configurations, which are used in the calculation of force and moment coefficients. These specified configurations must correspond to individual networks or to groups of networks; they cannot consist of a part of a network. Also, the force and moment coefficients on the configurations can be accumulated to obtain the values for a selected "total" configuration, which can consist of an individual network or a group of networks. Parts of the configuration which the user wants to exclude from the total force and moment coefficient calculation thus should be specified as separate networks.

The use of closure conditions (see section B.3.5) in design applications introduces another constraint on the definition of networks. The closure condition is the integral of the normal mass flux, multiplied by user-specified constants, over rows or columns of panels of a network. A closure condition can be applied to one network only, that is, a closure integral can not cover more than one network. (However, each design network can each have its own independent closure integral.)

The use of the PAN AIR update capability introduces other constraints on the definition of networks. The update capability allows computational economies in the modification of a given configuration, since selected networks can be modified or deleted without redefinition of the other networks. Appropriate definition of the networks will simplify the use of this capability. For example, if the location of some parts of the configuration will be changed in an update run, then those parts should be defined as separate network(s) in the original computer run.

Each network is defined by a user-specified rectangular array of grid points which define the corner points of quadrilateral panels. The indexing conventions used for each network are based on this user-specified array. The conventions are illustrated in figure B.1a where the three grid points numbered 1, 2, 3 along the left-hand edge of the network have been entered from top to bottom. This first column of points defines the first, second and last row of the array. All points in the second column are then input, again in the order of increasing row number, and so on through the last column of points. The direction of increasing row numbers is called the $\bar{M}$ direction and the direction of increasing column numbers is called the $\bar{N}$ direction, as shown in figure B.1b. The network size is defined by the numbers of rows (M) and columns (N) of grid points, figure B.1c. These define (M-1) rows and (N-1) columns of panels, figure B.1c. The array of network grid points may be triangular, that is, an edge (a "collapsed edge") may be a single point. However the grid points must still be defined as a rectangular array, with the common edge point defined repeatedly.

There are no restrictions upon the choice of the $\bar{M}$ and $\bar{N}$ directions. (For wake and design networks there is a preferred, but not required, choice which is discussed subsequently.) This is illustrated in figure B.2. On the network representing the top wing boundary surface, the $\bar{M}$ and $\bar{N}$ directions are arbitrarily chosen to be in the (nominally) streamwise and spanwise directions, respectively. On the fuselage network just aft of the wing, $\bar{M}$ and $\bar{N}$ are chosen to be in the circumferential and streamwise directions, respectively. This figure also illustrates the use of a collapsed edge for the pointed wing tip.

The network edge numbering convention is illustrated in figure B.3. Edges 1 and 3 are the first and last rows of grid points, respectively; edges 4 and 2 are the first and last columns of grid points, respectively. Figure B.3 also illustrates the double-index panel indexing convention. The ordering of the user-specified grid points (figure B.1a) can be interpreted as follows: the first column of grid points forms network edge 4, being ordered from network edge 1 to network edge 3. The other columns of points are input in the same order, with the last column forming network edge 2.

Two double-index conventions are used to label the network grid points and equivalently the panel corner points. The first convention is for "panel corner points," the row and column indices being those of the point row and point column, see figure B.1c. The second convention is for "enriched (or fine) panel corner points," in which the array is enriched by including all panel center points and panel edge mid-points. This indexing convention is illustrated in figure B.4.

The ordering of the rows and columns of grid points defines the positive direction of the network and panel normal vectors. The positive direction is defined as follows: if $\bar{N}$ and $\bar{M}$ are vectors in the directions of the point rows and columns, respectively, then the vector product $(\bar{N} \times \bar{M})$ is a vector pointing in the positive direction of the normal vector, figure B.5. The normal vector defines the "upper" and "lower" surfaces of the network, with the convention that the normal vector points outward from the upper surface. This definition is important since PAN AIR requires the specification of boundary conditions involving both the upper and lower network surfaces, see appendix A.3. The network upper and lower surfaces can be defined in an alternate but equivalent manner: if the viewer looks at the lower (upper) surface, figure B.3 for example, then the network edges are indexed in a clockwise (counter-clockwise) order.

For non-wake analysis networks the ordering of the network edges, and hence the orientation of the upper and lower surfaces of the network, have no general restrictions in PAN AIR. However, the orientation of the upper and lower surfaces should be compatible when the networks are combined to form a configuration. Incompatibility is not prohibited. However compatibility simplifies both preparation of the input data and interpretation of the program output. The orientation of wake network edges should satisfy the following rule, which is related to the corresponding arrays of "boundary condition location points" discussed in section B.3.4: for wake networks, edge 1 should be the leading (that is, most upstream) edge. This choice is preferred since it corresponds to the program default options for the boundary condition location points, but the choice is not required since these points can be put on any network edge by using record N12. For design networks the rules for the orientation of the network edges depend on the specific application, as discussed in section B.3.4.

A wake network is a special form of doublet network which is used to model shear layers. Two types of wake networks are available. One type (DW1) has constant doublet strength in one direction, which will be the (nominally) streamwise direction in physical applications. This network is used to model wakes trailing from lifting surfaces. A second type (DW2) of wake network has constant doublet strength throughout. It is used in a variety of special cases and to insure the continuity of wake surfaces, as discussed in the next section and in section B.3.6.1.

In supersonic flow it is necessary to distinguish between subinclined and superinclined panels. The distinction is critical for the formulation of the proper boundary conditions, as discussed in appendix A.3. A subinclined panel is one which is inclined behind the Mach cone, see figure A.5. A superinclined panel is one which is inclined ahead of the Mach cone, in which case no point on the panel lies in the domain of influence of any other point on the panel. If the panel is tangent to the Mach cone, it is called Mach-inclined; Mach-inclined panels are prohibited in PAN AIR.

### B.1.2 Modeling Guidelines

In modeling physical boundaries the user must first decide what is wanted from the computations. This decision dictates the theoretical model including the formulation of the boundary value problem and selection of the accuracy required. From this, the panel model is defined including specification of networks, selection of panel density, selection of possible approximations, and so forth. The primary point the user must consider is the tradeoff between the cost of the computer simulation and the required accuracy or effectiveness of the results.

There is a general guideline that finer paneling should be used in areas of primary interest and coarser paneling in areas of secondary interest. Two examples of this guideline in subsonic flow are shown in figure B.6. The first example, figure B.6a, is a study of the flow and pressures due to nacelle-wing interference. A detailed paneling has been used for the nacelle and the adjacent parts of the wing. A coarser paneling has been used for the inboard wing and for the body. This coarser paneling is adequate for representing the influence of the inboard wing and the body upon the nacelle and the adjacent part of the wing. The model may not be adequate for studying the flow on the body, but that is not the purpose of the study. The second example, figure B.6b, is a study of the flow and pressures on an empennage. Again a finer paneling is used in the area of interest; a coarser paneling is used in other areas. The effects of the wing and body upon the empennage are well represented, although the model may not be adequate for studying the flow on the wing and body themselves. When both fine and coarse grid paneling are used, abrupt transitions between the two should be avoided as much as possible, particularly if the flow is supersonic.

There is an additional requirement on panel density in curved regions. The basic panel analysis and the use of triangular subpanels approximately accounts for surface curvature, but a minimal density should be used in curved regions. As a guideline, a circular cross-section should be represented by a minimum of 18 panels to insure reasonable accuracy.

Supersonic flow problems introduce special considerations since local disturbances propagate throughout the flow. Thus the use of coarse paneling outside the region of primary interest may cause spurious results since the effects of the paneling in one region are not localized. An associated problem is the propagation of local Mach waves as would occur, for example, in a narrow channel in supersonic flow. A related example involving a nacelle installation on a highly swept wing is shown in figure B.7. Figure B.7a shows an idealization of the nacelle cross-section and the thin wing. With this idealization shock waves originating at the nacelle lip would be reflected off the wing and the nacelle body in a complex manner, requiring fine paneling throughout this region to retain fidelity. One way to eliminate the problem would be to model the wing-nacelle attachment in a more realistic manner, since the actual installation would have some fairings for boundary layer diversion. An alternate revision would be to add a frontal plate and side plates between the nacelle and wing, figure B.7b. New boundary conditions would be introduced to allow inflow through the frontal plate and a balancing outflow through the side plates.

Various linearized flow approximations can be selected by the user, see section 2.1.4. Again there is a tradeoff between the relative accuracy and cost of various analytical approaches. For example, since the compressibility vector $\hat{c}_0$ (see section B.2.1) is in the direction of the uniform onset flow, a change in that flow direction requires recomputation of the AIC matrix. In one form of linearized flow approximation a change in the flow direction can be represented by an onset flow, which results in changes in the boundary condition values. (Onset flows are discussed in section B.2.2.) However the original AIC matrix is used. This approach is very economical and is reasonably accurate in most cases. A related linearized flow approximation is the use of specified flows in the boundary condition equations as discussed in section B.3.2. In this approximation small changes in surface geometry, for example control surface deflections, can be represented in the boundary conditions without changing the geometry (which would require recomputing the AIC matrix). The specified flows can also be used, for example, to implement the thickness and camber approximations of classical thin airfoil theory.

The location of wake networks, which simulate shear layers in the flow, must be defined by the user. A reasonable estimate of the wake location is adequate in many applications. There are cases however where the wake location must be accurately known for reasonable prediction of the vehicle aerodynamics. An example is the interference between the wing wake and the horizontal tail, where small changes in the wing wake position can cause large changes in the pitching moment of the aircraft. Another example is a V/STOL vehicle where both the wing wake and the jet efflux from the engines must be accurately located. The location of wake networks can be treated as a design problem in PAN AIR, since one computer run with an initial estimate of the wake position will give results which can be used to locate the wake more accurately.

The use of wake networks and the importance of proper wake modeling is shown by the example in figure B.8. The configuration has a wing and body with one plane of symmetry. A type DW1 wake network is added which abuts the thin trailing edge of the wing along AB. This wake network allows the doublet strength to vary along the leading edge of the wake in order to match that at the wing trailing edge. The doublet strength matching boundary condition (see section B.3.5) is applied by PAN AIR along the network abutment AB. Since the outboard edge of the wake network abuts empty space, the doublet strength is zero there. If the inboard edge of the wake were also to abut empty space, the doublet strength would be zero there also. This is physically unrealistic and would cause unrealistic flow conditions on the wing due to the doublet strength matching condition at point B. This problem is corrected by filling the region between the body and the DW1 wake with type DW2 wake network, the leading edge of the DW2 network abutting the body along edge BC, abutting the inboard edge of the DW1 wake network, and abutting its own image in the plane of symmetry aft of point C.

Some other points regarding wake modeling are shown in figure B.8. The paneling of the DW1 wake should be either compatible or a refinement of the paneling of the abutting wing network(s). That is, every panel corner point of the DW1 wake network should match a panel corner point of the abutting wing network. (The paneling is not important for DW2 networks, since they have constant doublet strength.) Also, the wake networks, which must be truncated to finite length in a panel model, should be extended a sufficient length in the streamwise direction so that the truncation does not significantly

influence the flow on the physical configuration. Experience has shown that in subsonic flow a wake network behind a wing should have a length at least twenty times the wing chord length. (Type DW1 wake networks are usually not paneled in the direction of constant doublet strength, that is, in the direction of the flow. They can be extended an arbitrary distance in the flow direction without difficulty, except to avoid extremely long and narrow panels. See restriction number 5 in section B.1.3.1.)

Wake networks have an additional application as a method to obtain field flow properties, that is, velocities and pressures at points not on a physical or shear layer boundary. To do this a type DW2 wake network can be used. The single network control point (at the corner of network edges 1 and 4) must be located away from any other (non-null) network. Then the doublet strength will be zero because the program introduces a doublet strength matching condition at the control point. The source strength is always zero. The resulting null network will have no effect on the flow field. The surface flow properties can be calculated in the PDP module (surface flow properties data subgroup). The wake network must be tagged (record N6) so that the program will calculate and store the required information. In this case the paneling of the DW2 network is important.

### B.1.3 Restrictions on Panels, Networks, and Configurations

Each network is defined by a grid of user-specified panel corner points. These points define quadrilateral panels which need not be planar and which can be triangular in special cases. Each panel is divided into subpanels (by the program) which are used in the analysis of the boundary value problem.

#### B.1.3.1 Restrictions on Panels and Subpanels

1. Triangular Panels. Triangular panels must not occur inside a network. Panels can be triangular only at network edges and only if an entire edge is composed of triangular panels, in which case the "collapsed" edge is a single point. An example of a network with two nonadjacent collapsed edges, which is permissible, is given in figure B.9. The configuration of figure B.10 is prohibited due to the presence of both triangular and quadrilateral panels on edge AB. The situation in figure B.10 could be changed by the program check on the network triangular panel tolerance (record N7). If the average length of the four panel sides on edge AB is less than the tolerance, that edge will be collapsed to a point. All panels on the edge are then triangular, which is permissible. (If the average panel length on edge BC were also less than the tolerance, then that edge would also be collapsed; the network then would have two adjacent collapsed edges, which is an error.) (Version 1.0 of PAN AIR has the restriction: triangular panels are not allowed on networks with design boundary conditions.)

2. Almost Triangular Panels-1. The case of a quadrilateral panel with one side very much smaller than the others can cause numerical problems. To avoid this, a triangular panel tolerance (record N7) is specified by the user. If one side of a panel is shorter than the tolerance length, then

that side is collapsed to a point. An example of the application of this triangular panel definition capability is shown in figure B.11. If the collapsed panel edge is not part of the network edge, then a triangular panel occurs inside a network, which is an error. If the collapsed panel edge is part of the network edge then the previous restriction applies: if the edge is composed of triangular panels only (a collapsed edge) an error does not occur; if the edge is composed of both triangular and quadrilateral panels an error occurs.

3. Almost Triangular Panels-2. The case of a quadrilateral panel with three corner points on a straight line is discouraged. If three corner points are almost on a straight line, the program gives a diagnostic due to the possibility of subsequent numerical problems.

4. Non-Convex Panels. Non-convex panels are allowed, but the program gives a warning indicating their presence. An example of a non-convex panel is shown in figure B.12. An error occurs in the special case where the panel center point (which is the average of the four corner point coordinates) is located on a network edge.

5. Aspect Ratio. The distances from the panel center point to each edge are calculated; the panel aspect ratio is the ratio of the largest distance to the smallest distance. The aspect ratio of non-wake panels must be less than 10,000; a ratio larger than 10,000 causes an error. Smaller ratios are allowed, but the program gives a warning if the ratio is greater than 1,000 due to the possibility of subsequent numerical problems. There is no restriction on the aspect ratio of wake panels, but warnings are printed if poor least squares fits occur in the spline construction.

6. Mach-Inclined Panel or Subpanels. A panel or a subpanel must not be Mach-inclined, that is, tangent to a Mach cone, in which case the panel normal and conormal vectors are perpendicular: $(\hat{n} \cdot \tilde{n}) = 0$. If this occurs, the program gives an error.

7. Panels in Identical Location. Two or more panels must not have an identical location since this results in a singular AIC matrix. (No earlier warnings will occur.)

B.1.3.2 Restrictions on Networks

1. Non-Intersecting Networks. A network can not intersect itself. However, opposite edges of a network can abut; an example is shown in figure B.13.

2. Network Partly in a Plane of Symmetry. If a network is (completely or partly) located in a plane of symmetry, special treatment is required for its reflection in that plane. This avoids singularities which otherwise would occur because the input network and its image network have the same location. This special treatment is activated either by user-specification (record N5) or by a program check on the network location. (A user-specification takes precedence over the program check.) With the program check there is a restriction that the network can not be partly in a plane of symmetry. Specifically, the program checks the position of all panel center points relative to the plane(s) of symmetry. If all these points are within a user-specified tolerance

distance (record G7) of a plane of symmetry, then the special treatment is used. Figure B.14 illustrates the possible situations. In figure B.14a all network panel center points are within the tolerance distance of the plane of symmetry; the network would be specially treated. In figure B.14b all network panel center points are outside the tolerance distance; the network would not be specially treated, but would be reflected in the regular manner. In figure B.14c network panel center points occur both within and outside the tolerance distance, resulting in an error. (Other aspects of the special treatment of network reflection are discussed in section B.2.3.)

3. Network Abutments. The separately-defined networks are combined to form the configuration and flow boundary surfaces. The network edges meet at abutments, which are defined either by the user (geometric edge matching data group) or by the program. An abutment is a curve along which a particular set of network edges meet. Each abutment contains one or more network edges, with a maximum of five edges in an abutment. PAN AIR allows a general network abutment, with no requirement on compatibility of the network edges. An example of a general network abutment is shown in figure B.15. The abutment consists of segments A1 through A5 which consist of one, two or three network edges. Other examples of network abutments are given in appendix F of the Theory Document.

4. Network Abutments and Network Panels. In PAN AIR there are no strict requirements on the paneling of the networks at an abutment. However, as a rule of good modeling technique, the paneling of networks should be as compatible as possible at an abutment. (Violation of this rule may or may not significantly degrade the quality of the analysis.) For example, in figure B.15 the division of the abutment into segments A1 through A5 should correspond to panel corner points in the abuting networks. Similarly, panel corner points of abuting networks should coincide if possible. An example of this is the abutment of two networks, shown in figure B.16, one with a coarser paneling and one with a finer paneling at the abutment. Every panel corner point of the coarser grid should coincide with a corner point of the finer grid at the abutment. (The network with the finer grid is a "refinement" of the other network.) Abutments with non-matching panel corner points, such as occur at the wing-fuselage intersection of figure B.6b, can degrade the quality of the analysis, especially for supersonic flow, but are not prohibited. Also, if an abutment is supersonic, the panelling on the most downstream network edge should be equal or finer, that is, a "refinement," of the other edges in the abutment. A comparison of the requirements of an earlier program (reference B.1) and the modeling flexibility allowed by PAN AIR is given in figure B.17. Figure B.17a shows that PAN AIR does not require compatibility of network edges at an abutment. Figure B.17b shows that PAN AIR does not require identical paneling for two networks at an abutment. Figure B.17c shows how the flexibility allowed by PAN AIR can simplify the modeling of a simple configuration, resulting in less input data. Figure B.17c also shows an application of gap-filling panels, which are discussed in section B.3.5.

5. Network Abutments and Design Networks. The use of design boundary conditions introduces some special considerations in defining networks and network abutments. For design boundary conditions, there is a restriction that two abuting network edges can not both have control points. (See section B.3.4 for further discussion of control points, boundary condition location points and this restriction.) Also, to improve the quality of

the analysis, a design network edge with control points should not have coarser paneling than that of the other edges in the abutment. Network abutments and the associated edge matching boundary conditions are discussed in more detail in section B.3.5 and in appendix F of the Theory Document. Several associated points are also discussed there: smooth and non-smooth abutments, details of the automatic abutment procedure, gap-filling panels, the no doublet edge matching condition, and the closure condition.

### B.1.3.3 Restrictions on Configurations

PAN AIR optionally calculates the force and moment coefficients on individual panels, columns of panels, networks, and configurations formed from several networks. A program option allows the calculated force and moment coefficients to be accumulated to give the values for a group of user-defined configurations. The program identifies upper and lower surfaces of each network based upon the input ordering of the network grid points in the input data, see section B.1.1. There are advantages in ordering the grid points in a consistent manner, such that the upper surfaces are compatible when the networks are combined to form a configuration. An example of consistent ordering would be a thick configuration with all network upper surfaces located on the outside (or wetted) surface of the vehicle. This compatibility is not required, since the program allows the user to reverse the specification of the upper and lower network surfaces in forming a configuration (record SF2 and record FM8, option REVERSE). However, lack of compatibility results in extra input data. For example, the program default allows the user to specify the total (non-wake) configuration in a simple manner; this feature is useful only if all network upper and lower surfaces are ordered in a compatible manner.

## B.2 General Considerations

Several basic features of the PAN AIR system are described in this section. These include the coordinate systems, onset flows, and symmetries. These features are a necessary part of PAN AIR and allow simplifications in use of the system.

### B.2.1 Coordinate Systems

The PAN AIR user must define two basic coordinate systems. First, a "reference coordinate system" is used to specify the configuration geometry and the undisturbed flow field. Second, a "compressibility coordinate system" is required by the Prandtl-Glauert equation (A.1.1). (PAN AIR also uses coordinate systems which the user does not define, for example, local subpanel coordinate systems).

The reference coordinate system must be used to specify all geometry data for the configuration boundaries (the networks of panel grid points) and the incident flow fields. The reference coordinate system is a body axis systemfixed to the vehicle. The user may select any reference coordinate system provided it is orthogonal and right-handed. PAN AIR has an implied reference coordinate system: $x_o$-axis positive aft, $y_o$-axis positive right, and $z_o$-axis positive up. This system is used to define program default values and is used in all examples and figures in this document.

The compressibility coordinate system (x,y,z) is defined by the Prandtl-Glauert equation for the velocity potential.

$$(1-M_\infty{}^2)\,\phi_{xx} + \phi_{yy} + \phi_{zz} = 0 \qquad \text{(A.1.1)}$$

This equation has a preferred direction x, which is the compressibility axis. A compressibility vector $\hat{c}_o$ having unit length is defined in the direction of the compressibility axis. The axes of all Mach cones, for example, are in the direction of $\hat{c}_o$. The orientation of the other two axes (y and z) is arbitrary, provided the axis system is orthogonal and right-handed. The direction of the compressibility axis is unimportant in the special case of incompressible flow ($M_\infty = 0$), although a compressibility vector must be defined (program defaults can be used) to avoid numerical problems.

The compressibility coordinate system is defined by two rotations: a compressibility angle of attack $\alpha_c$ and a compressibility angle of sideslip $\beta_c$ (CALPHA and CBETA, record G5). The definition of the compressibility vector in the reference coordinate system is shown in figure B.18 for positive values of the two rotation angles. The compressibility coordinate system is obtained from the reference coordinate system by a rotation $(-\alpha_c)$ about the $y_o$-axis followed by a rotation $(-\beta_c)$ about the new position of the $z_o$-axis. Equivalently, the reference coordinate system is obtained from the compressibility coordinate system by a rotation $(+\beta_c)$ about the z-axis

followed by a rotation ($+\alpha_c$) about the new position of the y-axis. The associated transformation matrix is developed in appendix E.3 of the Theory Document.

Several other coordinate systems are introduced in the development of the force and moment coefficients, see section B.4.3. These coordinate systems have no effect upon the formulation and solution of the flow problem, since they are used only in the post-solution calculation of the force and moment coefficients.

## B.2.2 Onset Flows

Onset flows are used to define both the undisturbed flow field and special flow features. The undisturbed flow field is defined by the uniform onset flow velocity $\vec{U}_\infty$. This is specified by a magnitude and by the angles of attack and sideslip, $\alpha$ and $\beta$ (UINF, ALPHA and BETA, record G6). The direction of the uniform onset flow is obtained from the $x_0$-axis of the reference coordinate system by a rotation ($-\alpha$) about the $y_0$-axis followed by a rotation ($-\beta$) about the new position of the $z_0$-axis. The definition of the uniform onset flow in the reference coordinate system is shown in figure B.19for positive values of the two rotation angles. In the reference coordinate system the components of the uniform onset flow (see appendix E.3 of the Theory Document) are

$$\vec{U}_\infty = (U_\infty \cos\alpha \cos\beta, -U_\infty \sin\beta, U_\infty \sin\alpha \cos\beta) \qquad (B.2.1)$$

The use of the uniform onset flow is shown by the equation which determines the array of singularity parameters.

$$[AIC] \cdot \{\lambda\} = \{b\} \qquad (A.3.5)$$

One PAN AIR run allows one compressibility vector $\hat{c}_0$ and one Mach number, and consequently one aerodynamic influence coefficient matrix [AIC]. In an exact representation of the uniform flow field, the uniform onset flow must be in the direction of the compressibility vector, that is,

$$\vec{U}_\infty = \vec{V}_\infty$$

where $\vec{V}_\infty = |\vec{U}_\infty| \hat{c}_0$ and where $\alpha = \alpha_c$ and $\beta = \beta_c$. If the direction of the uniform onset flow changes, then the compressibility vector must also change. This requires computation of a new AIC matrix, which is relatively expensive. This can be avoided by using the approximation of linearized onset flow: changes in onset flow are represented as small changes about the original compressibility direction. The compressibility vector and consequently the AIC matrix are not changed. The allowable range by which $\alpha$ and $\beta$ can vary from $\alpha_c$ and $\beta_c$ and still give reasonable results is dependent on the Mach number. Typical ranges are $\pm 10^\circ$ at Mach 0.5, $+5^\circ$ at Mach 1.3 and $\pm 1^\circ$ at Mach 3.0.

The onset flow approximation gives the relation

$$\vec{V}_\infty = \vec{U}_\infty + \Delta\vec{U}^* \qquad (B.2.2)$$

where $\Delta\vec{U}^* = 0$ if $\alpha = \alpha_c$ and $\beta = \beta_c$. The quantity $\Delta\vec{U}^*$ is the difference between the velocity of the uniform flow field as specified by $\vec{V}_\infty$ in the compressibility direction (defined by $\alpha_c$ and $\beta_c$) and by $\vec{U}_\infty$ which has the same magnitude as $\vec{V}_\infty$ but a different direction (defined by $\alpha$ and $\beta$).

The distinction between $\vec{V}_\infty$ $(\alpha_c,\beta_c)$ and $\vec{U}_\infty$ $(\alpha,\beta)$ is further illustrated with the aid of figure B.20 for the special case of $\beta=\beta_c= 0$. Figure B.20a shows the freestream flow $\vec{V}_\infty$. The direction of $\vec{V}_\infty$ is denoted by the unit compressibility vector $\hat{c}_0$ along the compressibility axis. The orientation of this direction with respect to the $x_0$ axis is denoted by the symbol $\alpha_c$. Also shown in the figure is the mass flux boundary condition (see appendix H of the Theory Document) for an impermeable surface, that is,

$$(\vec{V}_\infty + \vec{w})\cdot\hat{n} = 0 \qquad \text{(B.2.3a)}$$

where $\vec{w}$ is the perturbation mass flux (see section A.2). For this boundary condition the elements of $\{b\}$ in equation (A.3.5) are $-\vec{V}_\infty \cdot \hat{n}$ and thus change whenever the angle $\alpha_c$ changes. But the AIC matrix of equation (A.3.5) is also a function of $\alpha_c$. Thus for equation (A.3.5) to be an "exact" numerical solution of equation (A.1.1), separate AIC matrices and separate right hand side vectors $\{b\}$ must be computed for each angle of attack.

For multiple angles of attack the "exact" procedure described above can be replaced by an approximate, but much less expensive procedure in which only the right-hand sides of the boundary conditions are modified, while keeping a single AIC matrix. This is illustrated in figure B.20b. The single user-specified angle $\alpha_c$ is used to create the AIC matrix. The uniform onset flow $\vec{U}_\infty$ has the same magnitude as $\vec{V}_\infty$ but is allowed to have a different orientation, defined by $\alpha$, so the boundary condition becomes

$$(\vec{U}_\infty + \vec{w})\cdot\hat{n} = 0 \qquad \text{(B.2.3b)}$$

In this way, a single AIC matrix is used to generate "solutions" for multiple angles of attack $\alpha$ (and in general for multiple combinations of the angles of attack $\alpha$ and sideslip $\beta$, and other onset flow quantities).

Use of any onset flow is restricted to defining different values of the constraint vector b on the right-hand side of equation (A.3.5). Consequently it is possible to have multiple constraint vectors b and corresponding multiple singularity parameter arrays $\lambda$. Equivalently equation (A.3.5) is rewritten as (see appendix L of the Theory Document)

$$[AIC]\,[\Lambda] = [B] \qquad \text{(B.2.4)}$$

where $[\Lambda]$ and $[B]$ are rectangular matrices with each column being a separate $\lambda$ and b vector. In PAN AIR terminology each column is a "solution" which can have different user-specified onset flows (record G6 and record set N18) and specified flows (record set 17). For each set of solutions there is only one AIC matrix or equivalently one set of $M_\infty$, $\alpha_c$ and $\beta_c$ values (record G5).

Extending the idea of onset flows, three basic types of onset flows can be specified in PAN AIR.

$$\vec{U}_o = \vec{U}_\infty + \vec{U}_{rot} + \vec{U}_{loc} \qquad \text{(B.2.5a)}$$

$$\Delta\vec{V} = \vec{U}_{rot} + \vec{U}_{loc} \qquad \text{(B.2.5b)}$$

where $\vec{U}_{rot} = \vec{\omega} \times (\vec{r} - \vec{r}_o)$

The quantity $\vec{U}_o$ is the total onset flow vector. Its composition is illustrated in figure B.21. The uniform onset flow $\vec{U}_\infty$ is defined in the reference coordinate system by a magnitude and by the angles of attack and sideslip $\alpha$ and $\beta$, equation (B.2.1). $\vec{U}_{rot}$ is the "rotational onset flow" at the field point $\vec{r}$, due to a rotation of the flow field (with respect to the vehicle), which is defined by a rotation reference point $\vec{r}_o$ and an angular velocity $\vec{\omega}$ of the flow (record G6). (Similarly $\vec{\omega}$ is the negative of the vehicle rotation rate in a steady, non-rotating flow.) $\vec{U}_{rot}$ is used for simulation of steady rotational motions of the flow. The quantity $\vec{U}_{loc}$ is the "local onset flow" (record set N18), which can be defined for each network or each control point of the configuration. An example of its use is the specification of the local onset flow due to propellers. The quantity $\Delta\vec{V}$ is the "incremental onset flow," which is the increment to the uniform onset flow. The incremental onset flow is used in two places in the analysis: in the boundary condition equations and optionally in the post-solution calculations of the pressure coefficients and the force and moment coefficients.

Extending the linearized onset flow approximation, the total mass flux is defined in terms of the total onset flow. Rewriting equation (A.2.2), the total mass flux is

$$\vec{W} = \vec{U}_o + \vec{w}$$

Similarly the mass flux boundary condition is defined in terms of the total onset flow. For example, the boundary condition of zero total normal mass flux for an impermeable surface is

$$\vec{W}\cdot\hat{n} = (\vec{U}_o + \vec{w})\cdot\hat{n} = 0 \qquad \text{(B.2.7)}$$

### B.2.3 Symmetries

The PAN AIR user can take advantage of two possible types of symmetry: configuration symmetry and flow symmetry (both specified in record G4). The distinction between the two follows from the basic equation (A.3.5). Configuration symmetry requires equal partitions in the AIC matrix (see section 5.7 and appendix K.1 of the Theory Document). Flow symmetry additionally requires equal partitions in the constraint vector b on the right-hand side. It is possible to have configuration symmetry without flow symmetry, but flow symmetry requires configuration symmetry. Configuration symmetry results in computational economies due to repetition of elements in

the AIC matrix. It also reduces the amount of required input data. Both configuration and flow symmetry allow computational economies in solving for the singularity parameters.

PAN AIR allows zero, one or two planes of configuration symmetry. In the last case the two planes must be orthogonal. The compressibility vector $\hat{c}_o$ must be in the plane(s) of configuration symmetry. The configuration symmetry must be complete, for example, it must include the geometries of both physical and wake surfaces. An example of the distinction between configuration and flow symmetries is shown in figure B.22. In figure B.22a the flow is asymmetric due to the non-zero angle of sideslip $\beta$ and the configuration is asymmetric due to the wake position. Since there is no configuration symmetry, the direction of the compressibility vector is unrestricted. Thus it can be chosen to be in the direction of the uniform onset flow, resulting in an exact flow modeling in terms of the Prandtl-Glauert equation. In figure B.22b the wake deflections are ignored in order to allow one plane of configuration symmetry. However the flow is still asymmetric (if $\beta$ is not zero). Since the configuration is symmetric to the $x_o$-$z_o$ plane, the compressibility vector $\hat{c}_o$ must be in that plane. Thus asymmetric flow with a symmetric configuration necessarily involves approximate flow modeling. Also for the symmetric configuration in supersonic flow, figure B.22b, the Mach lines will be symmetric since the compressibility vector is the axis of any Mach cone. The examples of figure B.22 show the choice that the user has: the exact model is inherently more accurate; the approximate model with configuration symmetry is more economical.

Where there are plane(s) of configuration symmetry, the user can request the flow properties on the input network and on all its images. This includes the surface flow properties (PDP module, using record SF2) and the forces and moments (CDP module, using record FM8). However, the specification of the calculations and the interpretation of the results require identification of the upper and lower surfaces of the input and the image networks. The sign of the normal vector, $\hat{n}$, is always changed in reflection through a plane of symmetry; that of $\bar{N}$ or $\bar{M}$ may also be changed. An example of a network and two planes of symmetry is shown in figure B.23. Figure B.23a shows a top view of the input network with its edge numbers: the normal vector points upward from the page. The image in the first plane of symmetry, including the edge numbers, is also shown. Here, the direction of $\bar{N}$ has been reversed, which with the (additional) sign change in $\hat{n}$, means that the normal vector of that image network points upward from the page. Reflections in the second plane of symmetry does not change the direction of either $\bar{M}$ or $\bar{N}$. The resulting normal vector is shown in figure B.23b. With these reflection rules each network (the input and its three images) has its upper surface exposed to the external flow field.

If a network occurs in a plane of symmetry, special treatment is required for analysis of the network and its image. This treatment by the program avoids singularities which otherwise would occur since the input and image networks have the same location. (For a discussion of the network properties which activate this treatment, see the second item under the restrictions on networks in section B.1.3.) The user must take special care in specifying boundary conditions and in interpreting the results for such a network. Figure B.24 shows in schematic form a network and its image in a plane of symmetry. The "interior" domain may have zero volume, but is considered since

boundary conditions must be specified on both surfaces of the input network (see section A.3). The best choice for the boundary condition is the condition of zero total normal mass flux, that is,

$$\vec{W} \cdot \hat{n} = 0$$

on the network surface exposed to the interior domain. (In theory this condition causes an ill-posed problem in the interior domain, but this difficulty is eliminated by the program in the special treatment of the network in a plane of symmetry. Also, this condition requires the use of class 4 boundary conditions, see section B.3.1.)

## B.3 Boundary Conditions

The properties of the flow field are determined by the Prandtl-Glauert equation and the corresponding integral equation. The solution of these equations requires a set of boundary conditions, which enable the user to specify the flow properties on network surfaces. A general boundary condition equation is used in the PAN AIR input, allowing the user to specify a variety of boundary conditions. Special classes and subclasses are defined to allow the user to specify standard boundary condition equations in an easy manner. The boundary condition equations are discussed in detail in appendix H of the Theory Document.

### B.3.1 Boundary Condition Equations

The physical vehicle boundary as well as flow field boundaries such as wakes, jet efflux tubes, and inlet and exhaust barriers are defined by networks. Boundary conditions are imposed on each network for the solution of the boundary value problem. In PAN AIR the number of boundary conditions specified on a network coincides with the number of unknown singularity parameters on that network. This condition, in conjunction with the network by network spline construction, makes each network logically independent of other networks.

The boundary conditions are of two general types, analysis and design, corresponding to the types of flow problems to which PAN AIR is applied. Analysis boundary conditions are for the following problem: given the flow conditions at the boundary, find the resulting flow field including the pressure distribution. PAN AIR has a non-iterative design capability which solves the following problem: given the conditions in the undisturbed flow field and the desired pressure distribution on network surface(s), find the resulting flow field including data needed for a linearized redesign of the original network surface(s).

The user can specify a maximum of two independent boundary condition equations at each control point (see section A.3). The two independent boundary conditions must apply to the two surfaces (the "upper" and "lower") of the network. However in many cases it is more convenient and economical to specify a linear combination of the two boundary conditions, particularly if one of the singularity strengths can be determined by so doing. The linear combination is equivalent to the original two boundary condition equations.

A general equation is used in PAN AIR to allow the user a wide choice of boundary conditions. The general boundary condition equation is composed of four separate relations, each involving perturbation flow quantities on the left-hand side. The first relation is the boundary condition for mass flux analysis: a mass flux is specified in the direction normal to the surface.

$$a_U(\vec{w}_U\cdot\hat{n}) + a_L(\vec{w}_L\cdot\hat{n}) + a_A(\vec{w}_A\cdot\hat{n}) + a_D\sigma = b_n\,\vec{U}_o\cdot\hat{n} + \beta_{nm} \qquad (B.3.1)$$

where U, L, A, D = upper, lower, average, difference (surfaces)

$\sigma = (\vec{w}_D\cdot\hat{n})$

$\beta_{nm}$ = user-specified normal mass flux

The second relation is the boundary condition for velocity potential analysis: a velocity potential function is specified at the surface.

$$c_U \phi_U + c_L \phi_L + c_A \phi_A + c_D \mu = b_p \vec{U}_\infty \cdot \vec{\Psi} + \beta_p \qquad \text{(B.3.2)}$$

where $\vec{\Psi} = (x/s\beta^2, y, z)$

$\mu = \phi_D$

$\beta_p$ = user-specified (perturbation velocity) potential

and where (x,y,z) are the control point coordinates in the compressibility axis system. (This relation can be used to specify perturbation or total potential on a surface, see section B.3.6 for examples.) The third relation is the boundary condition for velocity design: a flow velocity is specified in a direction tangent to the surface.

$$\vec{t}_U \cdot \vec{v}_U + \vec{t}_L \cdot \vec{v}_L + \vec{t}_A \cdot \vec{v}_A + \vec{t}_D \cdot \vec{v}_D = b_t \vec{t}_t \cdot \vec{U}_o + \beta_t \qquad \text{(B.3.3)}$$

where $\vec{t}$ = tangent vector coefficient (for subscripted velocity term)

$\beta_t$ = user-specified tangential perturbation velocity

The fourth relation is the boundary condition for velocity analysis: a flow velocity is specified in the direction normal to the surface.

$$e_U(\vec{v}_U \cdot \hat{n}) + e_L(\vec{v}_L \cdot \hat{n}) + e_A(\vec{v}_A \cdot \hat{n}) + e_D(\vec{v}_D \cdot \hat{n}) = b_n \vec{U}_o \cdot \hat{n} + \beta_{nv} \qquad \text{(B.3.4)}$$

where $\beta_{nv}$ = user-specified (perturbation) normal velocity

Although the velocity analysis boundary condition is provided for the user, the standard PAN AIR formulation uses mass flux boundary conditions for analysis with impermeable surfaces (see sections 5.4 and B.0 of the Theory Document).

To solve the integral equation associated with the Prandtl-Glauert equation (A.1.1), the Prandtl-Glauert transformation is used.

$$\bar{x} = x$$

$$\bar{y} = \beta y$$

$$\bar{z} = \beta z \qquad \text{(B.3.5)}$$

The original Prandtl-Glauert equation has two standard forms in the new coordinates: Laplace's equation in subsonic flow, and the wave equation in supersonic flow. The basic integrals, that is, the panel influence coefficients, required to solve the Prandtl-Glauert equation are evaluated in the transformed coordinates. These are then transformed to the original reference coordinates before applying the boundary conditions.

In PAN AIR the user can choose either mass flux or velocity boundary conditions, equation (B.3.1) or (B.3.4). For subsonic flow the mass flux boundary condition applied to the real geometry gives the same solution for

the velocity potential as the velocity boundary conditions applied to the equivalent incompressible geometry obtained by using the Prandtl-Glauert transformation, equation (B.3.5). The velocity boundary conditions applied to the real geometry give what is called the "Gothert Rule II" in reference B.2. These boundary conditions can be imposed in PAN AIR by using class 4 or class 5 boundary conditions (see discussion below). However the standard PAN AIR formulation is based upon the mass flux boundary conditions; the user-convenience features (that is, the boundary condition classes listed below) are accordingly designed with that case in mind.

The general PAN AIR input boundary condition equation is the sum of equations (B.3.1) to (B.3.4) and is given in figure B.25. The duplicate terms for the normal component of the total onset flow which appear on the right-hand sides of equations (B.3.1) and (B.3.4) are replaced by a single term. The four $\beta$ quantities ("specified flows") are combined into a single term to simplify the data input (record set N17).

The preceding form of the boundary condition equations is redundant since it includes both the upper-lower and average-difference pairs of terms. This redundant form is used for the program input since it allows the user to specify boundary condition equations in the general form. Within PAN AIR the input terms are combined to give the total average-difference terms (see appendix H.1 of the Theory Document). The procedure is based upon the relations between the average-difference quantities and the upper-lower quantities. For example, the relations for the mass flux are

$$\vec{w}_A = 1/2\ (\vec{w}_U + \vec{w}_L) \qquad \text{(B.3.6a)}$$

$$\vec{w}_D = (\vec{w}_U - \vec{w}_L) \qquad \text{(B.3.6b)}$$

A standard set of boundary condition classes is defined to simplify the input data required for frequently used problems. The standard boundary condition classes (record N9) are

| Class | Boundary Condition |
|---|---|
| 1 | Impermeable Surface Mass Flux Analysis |
| 2 | Specified Normal Mass Flux Analysis |
| 3 | Specified Tangential Velocity Design |
| 4 | Selected Terms |
| 5 | General Boundary Condition Equation |

The selection of a boundary condition class and associated subclass results in the specification of two boundary condition equations for each control point. Depending on the class and subclass, the user may be required to supply additional data for the boundary condition equations.

Classes 1 and 2 define mass flux analysis boundary conditions. Class 1 defines boundary conditions of zero mass flux normal to the surface and is appropriate for flow over impermeable surfaces. With selection of class 1 boundary conditions (with appropriate subclass), the boundary condition equations are completely specified; the user is not required to supply any additional information. However the user can optionally specify different onset flows (global, rotational and local) which contribute to the total onset flow term on the right-hand side, $b_n\ \vec{U}_o \cdot \hat{n}$, figure B.25. Class 1 boundary

conditions are discussed in section 3.3. Class 2 defines boundary conditions with a specified mass flux normal to the surface. With class 2 the boundary condition equations are completely specified, except for the specified flow terms on the right-hand side which the user must specify (record set N17). Class 2 boundary conditions are discussed in section B.3.2.

Class 3 defines design boundary condition equations with a specified velocity tangent to the surface. The user must specify the surface tangent vector coefficients (record set N16), with two standard options available to simplify this requirement. The user must, in most cases, specify a closure condition (record set N14) for each network with class 3 boundary conditions. The user must also supply the specified flows (record set N17) which specify the tangential velocities or pressure coefficients at the control points. Class 3 boundary conditions are discussed in section B.3.3.

Class 4 boundary conditions allow the user to select one term each from the left and right-hand side terms of the general boundary condition equation, figure B.25. Standard numerical values are assigned to the coefficients of the selected terms (values are +1 for left-hand side terms and ±1 or 0 for right-hand side terms). Exceptions are terms involving the tangent vector coefficients (record set N16) and the specified flow terms (record set N17) both of which must be supplied by the user.

Class 5 boundary conditions allow the user to select any combination of terms from the general boundary condition equation, figure B.25. The user must supply numerical values of the coefficients of the selected terms (record set N15). The class 5 option allows almost complete generality in specifying the boundary condition equations, but requires the most input data and the most user knowledge to formulate the boundary condition equations.

Two other types of boundary condition equations can also be specified. One is the closure condition. This is used in design applications and is discussed in section B.3.5. The other is the singularity strength matching or edge matching boundary condition and is discussed in section B.3.5.

The manner in which the PAN AIR boundary condition capability can be used to construct models representing physical flow problems is illustrated by several examples in section B.3.6. Additional examples appear in section B.3.2 for class 2, subclass 5 boundary conditions which are used to model lifting surfaces in the spirit of classical thin wing theory.

### B.3.2 Specified Normal Mass Flux Analysis (Class 2) Boundary Conditions

This class of boundary value problems is an extension of class 1 (impermeable surface) boundary conditions to allow a "specified flow" through the surface. The specified flow is a user-specified normal mass flux on the right-hand side of the boundary condition equation(s). A common application of class 2 boundary conditions is linearized surface modeling with specified flows used to simulate surface thickness, camber and deflection. This is an application of classical thin wing theory (references B.3 and B.4). Other applications are the simulation of flow entrainment and the representation of inlet flow and jet effluxes.

Class 2 boundary conditions are grouped into five subclasses listed in table B.1 (also figure 7.5). The boundary conditions apply either to thick bodies (subclasses 1 and 2) or to thin bodies (subclasses 3, 4 and 5). For thick bodies, subclasses 1 and 2 correspond to the case of the upper and lower surfaces wetted by the physical flow field, respectively. For thin bodies, subclasses 3, 4 and 5 correspond to different forms of the specified flow. Subclass 5 is the general case which includes the other two subclasses as special cases. The boundary condition equations are described below for each subclass.

| Subclass* | Subclass Description |
|---|---|
| 1 - UPPER | Specified Normal Mass Flux on Upper Surface |
| 2 - LOWER | Specified Normal Mass Flux on Lower Surface |
| 3 - DEFLECTION | Linearized Deflection on Average (Cambered) Surface |
| 4 - THICKNESS | Thickness on Average (Cambered) Surface |
| 5 - BOTH | Both Deflection and Thickness on Average Surface |

* Program Index-Keyword

Table B.1 Subclasses for class 2 boundary conditions

The general class 2 boundary condition equation is the statement that the normal component of the total mass flux is equal to a specified normal mass flux on the surface.

$$\vec{W}\cdot\hat{n} = \beta_{nm} \tag{B.3.7}$$

The total linearized mass flux is the sum of the total onset flow and the perturbation mass flux, see the development of equation (B.2.6).

$$\vec{W} = \vec{U}_o + \vec{w} \tag{B.3.8}$$

Combining equations (B.3.7) and (B.3.8), the relation for the normal component of the perturbation mass flux is

$$\vec{w}\cdot\hat{n} = -\vec{U}_o\cdot\hat{n} + \beta_{nm} \tag{B.3.9}$$

The specified flow $\beta_{nm}$ is the normal mass flux issuing from the surface.

For a linearized surface representation the specified flow is equal to that amount required to turn the flow through specified angles. For a linearized representation of a change of surface position the specified flow is equal to the difference between the products of the onset flow velocity and the surface slope for the represented surface and the original user-specified surface, figure B.26.

$$\beta_{nm} = \Delta \left[ U_o \quad \frac{\partial z_o}{\partial x_o} \right] \tag{B.3.10}$$

In boundary condition class 2, equation (B.3.9) is applied either at the upper surface (subclass 1) or at the lower surface (subclass 2) of a network. It is also applied at both surfaces (subclasses 3 to 5) in the form of the average and difference of the upper and lower surface values. Equation (B.3.10) is similarly applied to the upper, lower, or both surfaces for a linearized representation of a position change of the surface(s).

As mentioned above, class 2 boundary conditions are extensions of class 1 boundary conditions: for non-wake networks a class 1 problem can be run as a class 2 problem with the specified flow term(s) set to zero. The two problems will give the same solution for the singularity parameters. However there are differences in the post-solution modules which will cause two basic differences between the results for the two problems. First, the post-solution calculations are more efficient for the class 1 problem. Second, there may be small differences in the computed flow velocities.

B.3.2.1 Class 2 - Subclass 1 (UPPER)

This boundary condition subclass is the condition of specified normal mass flux on the upper surface of a thick configuration as shown in figure B.27. The upper surface of the thick configuration is wetted by the physical flow, figure B.27a. (The upper surface has the outward-pointing normal vector.) The equations used by the program are

$$\sigma = -\vec{U}_o \cdot \hat{n} + \beta_{n1} \tag{B.3.11a}$$

$$\phi_L = 0 \tag{B.3.11b}$$

The lower surface is assigned the boundary condition of perturbation stagnation, equation (B.3.11b). It is assumed that all other network surfaces circumscribing the domain have the same boundary condition. Since the entire surface of the domain has the zero potential boundary condition, the perturbation potential is zero in the entire domain. Thus both the potential and its gradient are zero on the lower surface of the network. Similarly the perturbation mass flux is zero, or in terms of its normal component

$$\vec{w}_L \cdot \hat{n} = 0 \tag{B.3.12}$$

The other boundary condition, equation (B.3.11a), is the condition of specified total normal mass flux on the upper surface of the network. Writing equations (B.3.7) and (B.3.9) for the upper surface, this condition is (in two equivalent forms)

$$\vec{w}_U \cdot \hat{n} = \beta_{nmU} \tag{B.3.13a}$$

$$\vec{w}_U \cdot \hat{n} = -\vec{U}_o \cdot \hat{n} + \beta_{nmU} \tag{B.3.13b}$$

Using equation (A.2.5a) to introduce the source strength,

$$\sigma = (\vec{w}_U - \vec{w}_L) \cdot \hat{n} \tag{A.2.5a}$$

and subtracting equation (B.3.12) from equation (B.3.13b) gives

$$\sigma = - \vec{U}_o \cdot \hat{n} + \beta_{nmU} \qquad \text{(B.3.14)}$$

This becomes equation (B.3.11a) when the specified flow is identified in the program notation as $\beta_{n1}$; the subscript 1 is used to identify the first boundary condition equation. Accordingly, the user must supply the specified flow terms (record set N17) for the first equation. Otherwise the boundary condition equations (B.3.11a) and (B.3.11b) are completely defined by specifying the class and subclass (record N9).

For zero total mass flux normal to the upper surface, the specified flow $\beta_{n1}$ is zero by equation (B.3.13a). In this case $\sigma = \vec{w}_U \cdot \hat{n} = - \vec{U}_o \cdot \hat{n}$, that is, the known source strength generates an amount of upper surface perturbation normal mass flux which exactly cancels the normal component of the total onset flow, figure B.27b. This is the mass flux boundary condition for an impermeable surface. Any positive (negative) increment $\beta_{n1}$ to this source strength will cause a net mass flux to flow from the upper surface in the positive (negative) $\hat{n}$-direction. This is illustrated in figure B.27c for the case of positive $\beta_{n1}$. For a linearized surface representation the specified flow is equal to the difference in the product of the total onset flow and the surface slope between the actual and represented upper surface, equation (B.3.10) and figure B.26.

The two boundary condition equations are special cases of the general relation, equation (B.3.1) to (B.3.4). Equation (B.3.11a) is a special case of equation (B.3.1) with $a_U = 1$, $b_n = -1$ and the other coefficients equal to zero; the specified flow is supplied by the user (record set N17). Equation (B.3.11b) is a special case of equation (B.3.2) with $c_L = 1$ and all other coefficients equal to zero.

B.3.2.2 Class 2 - Subclass 2 (LOWER)

This boundary condition subclass is the condition of specified normal mass flux on the lower surface of a thick configuration as shown in figure B.28. The lower surface of the thick configuration is wetted by the physical flow, figure B.28a. This problem is the same as subclass 1 (UPPER), except that the definition of the upper and lower surfaces (or equivalently the direction of the network normal vector) is reversed. The equations used by the program are

$$- \sigma = - \vec{U}_o \cdot \hat{n} + \beta_{n1} \qquad \text{(B.3.15a)}$$

$$\phi_U = 0 \qquad \text{(B.3.15b)}$$

The upper surface is assigned the boundary condition of perturbation stagnation, equation (B.3.15b). It is assumed as in subclass 1 that the zero potential boundary condition is applied on all surfaces circumscribing the domain. Consequently the perturbation mass flux is zero on the upper surface, or in terms of the normal component

$$\vec{w}_U \cdot \hat{n} = 0 \qquad \text{(B.3.16)}$$

The other boundary condition equation is the condition of specified total normal mass flux on the lower surface of the network. Writing equations (B.3.7) and (B.3.9) for the lower surface, this condition is (in two equivalent forms)

$$\vec{w}_L \cdot \hat{n} = \beta_{nmL} \qquad \text{(B.3.17a)}$$

$$\vec{w}_L \cdot \hat{n} = -\vec{U}_o \cdot \hat{n} + \beta_{nmL} \qquad \text{(B.3.17b)}$$

Equation (B.3.15a) is obtained by subtracting equation (B.3.16) from equation (B.3.17b) and using the defining property of the source strength at a control point, equation (A.2.5a). The resulting boundary condition equation is

$$-(\vec{w}_U - \vec{w}_L) \cdot \hat{n} = -\sigma = -\vec{U}_o \cdot \hat{n} + \beta_{nmL} \qquad \text{(B.3.18)}$$

In program notation the specified flow is identified as $\beta_{n1}$; the subscript 1 is used to identify the first boundary condition equation. This equation is the same as equation (B.3.11a) for subclass 1, except for the minus sign on the source strength. This sign change is due to the interchange of the upper and lower surfaces, and to the ordering of the normal mass fluxes on the upper and lower surfaces in the definition of the source strength, equation (A.2.5a).

For zero total mass flux normal to the lower surface, the specified flow $\beta_{n1}$ is zero by equation (B.3.17a), that is, the known source strength generates an amount of perturbation normal mass flux on the lower surface which exactly cancels the normal component of the total onset flow. Any positive (negative) increment $\beta_{n1}$ to this source strength will cause a net mass flux to flow from the lower surface in the negative (positive) $\hat{n}$ direction, figure B.28b.

### B.3.2.3 Class 2 - Subclass 3 (DEFLECTION)

This boundary condition subclass is the condition of specified average normal mass flux on a thin ("average") configuration as shown in figure B.29. This subclass is used for a linearized representation of surface camber or deflection on the input network. The surface thickness is ignored. The equations used by the program are

$$\sigma = 0 \qquad \text{(B.3.19a)}$$

$$\vec{w}_A \cdot \hat{n} = -\vec{U}_o \cdot \hat{n} + \beta_{n2} \qquad \text{(B.3.19b)}$$

These equations are discussed below in the section on class 2, subclass 5 boundary conditions, since subclass 3 is a special case of subclass 5.

B.3.2.4 Class 2 - Subclass 4 (THICKNESS)

This boundary condition subclass is the condition of specified normal mass flux difference on a thin configuration as shown in figure B.29. This subclass is used for a linearized representation of a surface with (symmetric) thickness on the input network. There is no linearized representation of a change in the surface camber, that is, the surface camber is that of the input network. The equations used by the program are

$$\sigma = \beta_{n1} \tag{B.3.20a}$$

$$\vec{w}_A \cdot \hat{n} = - \vec{U}_o \cdot \hat{n} \tag{B.3.20b}$$

These equations are discussed below in the section on class 2, subclass 5 boundary conditions, since subclass 4 is a special case of subclass 5.

B.3.2.5 Class 2 - Subclass 5 (BOTH)

This boundary condition subclass is the general condition of specified normal mass flux on a thin configuration. It is used for a linearized representation of thickness and camber (or deflection) on the input network. The equations used by the program are

$$\sigma = \beta_{n1} \tag{B.3.21a}$$

$$\vec{w}_A \cdot \hat{n} = - \vec{U}_o \cdot \hat{n} + \beta_{n2} \tag{B.3.21b}$$

Subclass 5 includes as special cases both subclass 3 ($\beta_{n1}$ equal to zero) and subclass 4 ($\beta_{n2}$ equal to zero).

Subclass 5 deals with thin configurations representing approximations to actual wing or tail configurations in the spirit of classical thin wing theory. The term thin configuration refers to a source and/or doublet sheet (a PAN AIR composite network) as shown in figure B.29. At the upper and lower surfaces of this network, the following expressions are written for the total normal mass flux, using equations (B.3.7) and (B.3.8).

$$\vec{w}_U \cdot \hat{n} = (\vec{U}_o + \vec{w}_U) \cdot \hat{n} = \beta_{nmU} \tag{B.3.22a}$$

$$\vec{w}_L \cdot \hat{n} = (\vec{U}_o + \vec{w}_L) \cdot \hat{n} = \beta_{nmL} \tag{B.3.22b}$$

Subtracting and averaging these two equations gives

$$(\vec{w}_U - \vec{w}_L) \cdot \hat{n} = \beta_{nmU} - \beta_{nmL} \tag{B.3.23a}$$

$$1/2(\vec{w}_U + \vec{w}_L) \cdot \hat{n} = - \vec{U}_o \cdot \hat{n} + 1/2 \, (\beta_{nmU} + \beta_{nmL}) \tag{B.3.23b}$$

Using equations (B.3.6a) and (B.3.6b), these equations can be written as

$$\vec{w}_D \cdot \hat{n} = \sigma = \beta_{n1} \tag{B.3.24a}$$

$$\vec{w}_A \cdot \hat{n} = - \vec{U}_o \cdot \hat{n} + \beta_{n2} \qquad \text{(B.3.24b)}$$

in terms of the difference and average normal mass fluxes; where equation (A.2.5a) has been used to introduce the source strength $\sigma$, and where

$$\beta_{n1} = \beta_{nmU} - \beta_{nmL} \qquad \text{(B.3.25a)}$$

$$\beta_{n2} = 1/2 \ (\beta_{nmU} + \beta_{nmL}) \qquad \text{(B.3.25b)}$$

Both equation (B.3.24a) and (B.3.24b) are special cases of the general normal mass flux boundary condition, equation (B.3.1). The numerical indices on the two specified flows have no physical meaning; they are merely identifiers used to place user-specified input data into the proper boundary condition equation.

The specified flow terms have special forms for linearized representation of thickness and camber on a thin configuration. Two simulated surface slopes are defined, one (a) for the top and one (b) for the bottom boundaries of a thick configuration. The total specified flow is separated into two parts. The first part is the representation of the (symmetric) thickness relative to the original boundary surface of the thin configuration. Applying equation (B.3.10) to the upper and the lower surfaces of the network gives the relation

$$\beta_{n1} = U_o \left[ \Delta \left. \frac{\partial z_o}{\partial x_o} \right|_a \quad - \Delta \left. \frac{\partial z_o}{\partial x_o} \right|_b \right] \qquad \text{(B.3.26a)}$$

This specified flow is the product of the total onset flow and twice the slope of the symmetric thickness, referred to as the "slope of thickness form."

$$\beta_{n1} = U_o \ \frac{\partial z_{ot}}{\partial x_o} \quad \text{of thickness form} \qquad \text{(B.3.26b)}$$

The second part is the representation of the (anti-symmetric) camber relative to the original surface of the thin configuration. Again applying equation (B.3.10) to the upper and the lower surfaces of the network gives the relation

$$\beta_{n2} = \frac{1}{2} U_o \left[ \Delta \left. \frac{\partial z_o}{\partial x_o} \right|_a + \Delta \left. \frac{\partial z_o}{\partial x_o} \right|_b \right] \qquad \text{(B.3.27a)}$$

$$\beta_{n2} = U_o \ \frac{\partial z_{oc}}{\partial x_o} \quad \text{of surface camber} \qquad \text{(B.3.27b)}$$

This specified flow is the product of the total onset flow and the slope of the cambered surface.

An example of the use of specified flow to simulate a thick cambered configuration is shown in figure B.30. The flat input network is in the $x_o$-$y_o$ plane. Two functions are given for the top, $z_{oa}(x_o)$, and the bottom, $z_{ob}(x_o)$, of the airfoil boundaries. The difference between the top and bottom boundaries is the simulated thickness, whose slope multiplied by the total onset flow gives $\beta_{n1}$, equations (B.3.26a) and (B.3.26b). The average

of the top and bottom boundaries is the simulated camber, whose slope multiplied by the total onset flow gives $\beta_{n2}$, equations (B.3.27a) and (B.3.27b).

The general case of simulation of a thick cambered configuration includes the special cases of simulation of surface camber or deflection without thickness and of surface thickness without camber or deflection. Equivalently the boundary condition equations for subclass 5 include as special cases the equations for subclass 3 and subclass 4, respectively.

The use of subclass 3 boundary conditions is illustrated by the two examples in figures B.31 and B.32. Figure B.31 shows the case of a simulated camber line $z_{oc}(x_o)$ modeled with a flat doublet network (that is, the source strength is zero). If $z_{oc}$ were zero everywhere, the perturbation normal mass flux would have to be equal to $-\vec{U}_o \cdot \hat{n}$ to cancel the normal component of the onset flow and hence make the resultant average total mass flux parallel to the $x_o$ axis. For nonzero $z_{oc}$ the doublet sheet must produce an extra amount of normal mass flux $\beta_{n2}$ such that the flow is turned through the angle $\theta(x_o)$ and hence the resultant flow is tangent to $z_{oc}$. Thus, $\beta_{n2}$ is given by

$$\beta_{n2} = \left| \vec{U}_o + \vec{w}_A \right| \tan \theta \approx U_o \frac{\partial z_{oc}}{\partial x_o}$$

Figure B.32 shows the simulation of a deflected flap while using the input network geometry of the undeflected flap. The solid curve denoted $z_{oi}(x_o)$ is the location of two doublet networks representing a thin cambered wing with an undeflected trailing edge flap. For this case the resultant average mass flux is made tangent to the input geometry $z_{oi}(x_o)$ by setting $\beta_{n2}$ to zero in equation (B.3.21b). To simulate a deflected flap location, denoted by the dashed curve $z_{of}(x_o)$, network 2 is made to produce an additional average mass flux $\beta_{n2}(x_o)$, normal to $z_{oi}(x_o)$, such that the flow is turned through the flap angle $\delta$. For small values of changes in both the slopes and the perturbation mass flux, $\delta$ is given by

$$\delta \approx \Delta \frac{\partial z_{oc}}{\partial x_o} = \frac{\partial z_{of}}{\partial x_o} - \frac{\partial z_{oi}}{\partial x_o}$$

and the required normal mass flux for network 2 is

$$\beta_{n2} = U_o \Delta \frac{\partial z_o}{\partial x_o} \qquad \text{(B.3.29)}$$

The use of subclass 4 boundary conditions is illustrated in figure B.33, which shows a linearized representation of a thin configuration with (symmetric) thickness but without camber. This allows the symmetric thickness to be simulated by letting

$$\beta_{nmU} = \frac{1}{2} U_o \frac{\partial z_o}{\partial x_o}$$

$$\beta_{nmL} = -\frac{1}{2} U_o \frac{\partial z_o}{\partial x_o}$$

For the input network to be impermeable the boundary condition is $\vec{W}_A \cdot \hat{n} = 0$, hence $\beta_{n2}$ is zero in equation (B.3.21b). By equation (B.3.25b), $\beta_{n2} = 1/2\ (\beta_{nmU} + \beta_{nmL}) = 0$, hence the upper and lower surface normal mass fluxes are of equal magnitude but in opposite directions. By equation (B.3.25a)

$$\beta_{n1} = U_o \frac{\partial z_{ot}}{\partial x_o} \tag{B.3.30}$$

in equation (B.3.21a). This user-specified set of $\beta_{n1}$ values will cause the source strength $\sigma = \beta_{n1}$ to be of such magnitude that the flow is tangent to the thickness form $z_{ot}(x_o)$. Thus the subclass 4 or subclass 5 boundary conditions are given by equations (B.3.21a) and (B.3.21b), with $\beta_{n1}$ given by equation (B.3.30) and $\beta_{n2} = 0$, that is,

$$\sigma = U_o \frac{\partial z_{ot}}{\partial x_o} \tag{B.3.31a}$$

$$\vec{w}_A \cdot \hat{n} = -\vec{U}_o \cdot \hat{n} \tag{B.3.31b}$$

B.3.3 Design (Class 3) Boundary Conditions

Class 3 boundary conditions involve the specification of the surface pressure coefficient or equivalently the tangential velocity component on a given surface. Class 3 boundary condition equations are grouped into six subclasses which are listed in table B.2 (also figure 7.6). The boundary conditions apply either to thick bodies (subclasses 1 and 2) or to thin bodies (subclasses 3 through 6). The boundary conditions are used in the design of network(s) to satisfy a given pressure coefficient distribution (see section C of the Theory Document). Examples of design problems are given (cases 7 and 8) in the Case Manual.

| Subclass* | Subclass Description |
|---|---|
| 1 - UPPER | Upper Surface Design |
| 2 - LOWER | Lower Surface Design |
| 3 - THICKNESS | Thickness Design with Given Camber |
| 4 - CAMBER | Camber Design with Given Thickness |
| 5 - THICKNESS CAMBER | Thickness and Camber Design |
| 6 - BOTH | Upper and Lower Surface Design |

* Program Index-Keyword

Table B.2 Subclasses for class 3 boundary conditions

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The general class 3 boundary condition specifies the tangential velocity distribution on one or both network surfaces. The boundary condition equation has the general form

$$\hat{t} \cdot \vec{V} = \beta_t \qquad \text{(B.3.32)}$$

where $\hat{t}$ is a unit vector tangent to the surface, $\vec{V}$ is the total velocity on the surface and $\beta_t$ is a specified flow term related to the pressure coefficient on the surface. In words, the tangential component of the total fluid velocity at the surface is equal to a user-specified value related to the pressure coefficient.

For an example of the development of the specified flow term $\beta_t$, a particular pressure coefficient-tangential velocity relation is used.

$$C_p = 1 - (\vec{V} \cdot \hat{t}/V_\infty)^2 \qquad \text{(B.3.33)}$$

This relation is one of the pressure coefficient rules available in PAN AIR (record G12, option REDUCED-SECOND-ORDER) and is discussed in section B.4.2. It is exact for incompressible flow and is approximate for compressible flow.

Two possible approaches for determining the specified flow term are described here. In the first approach the pressure coefficient desired by the user is given (see appendix C of the Theory Document). Rewriting equation (B.3.33) and using equation (B.3.32), the specified flow is

$$\beta_t = V_\infty \left(1 - \frac{1}{2} C_p\right) \qquad \text{(B.3.34)}$$

where it has been assumed that $|C_p| \ll 1$ . In the second approach the pressure coefficient is expressed in terms of a known value, $C_{po}$, and the pressure coefficient desired by the user, $C_p$ (reference B.5). Using equations (B.3.32) and (B.3.33), the specified flow is

$$\beta_t = V_\infty \sqrt{1 - C_{po}} \left[ 1 - \frac{1}{2} \frac{(C_p - C_{po})}{(1 - C_{po})} \right] \qquad \text{(B.3.35)}$$

where it has been assumed that $|C_p - C_{po}| \ll |1 - C_{po}|$

The choice between the specified flows of equations (B.3.34) and (B.3.35) depends upon the specific application: design to a given pressure coefficient in the former case, and redesign to a given change in pressure coefficient in the latter case. For more complicated pressure coefficient-velocity relations, for example, isentropic, the relation between the pressure coefficient and the specified flow $\beta_t$ would be determined numerically.

The unknown total velocity is the sum of the total onset flow velocity and the perturbation velocity

$$\vec{V} = \vec{U}_o + \vec{v}$$

Combining equations (B.3.32) and (B.3.36), the boundary condition becomes

$$\hat{t} \cdot \vec{v} = -\hat{t} \cdot \vec{U}_o + \beta_t \qquad \text{(B.3.37)}$$

This is the general form of the design boundary condition equation. It can be applied to the upper and/or lower surface of a network.

In PAN AIR a more general equation is allowed for class 3 boundary conditions, namely

$$\vec{t} \cdot \vec{v} = -\vec{t}_t \cdot \vec{U}_o + \beta_t \qquad \text{(B.3.38)}$$

Here the tangent vectors ("tangent vector coefficients") are not restricted to be unit vectors, and different vectors can be used on the left and right-hand sides of equation (B.3.38). These options give the user flexibility in formulating design boundary conditions. However, the input data for the tangent vectors is simpler in the standard case of equation (B.3.37): unit vectors are specified as the default option, and both left and right-hand side vectors (and vectors for a second boundary condition equation) can be specified by the same numerical data. Also, all examples of development of specified flows are based on equation (B.3.37) in the subsequent discussion.

### B.3.3.1 Class 3 - Subclass 1 (UPPER)

This boundary condition subclass is the design problem on the upper surface of a thick configuration, figure B.34, with the upper surface wetted

by the physical flow. (The upper surface has the outward pointing normal vector.) This subclass defines equations for the design of the network upper surface with a user-specified pressure coefficient. The equations used by the program are

$$\vec{t}_U \cdot \vec{v}_U = -\vec{t}_{t1} \cdot \vec{U}_o + \beta_{t1} \qquad \text{(B.3.39a)}$$

$$\phi_L = 0 \qquad \text{(B.3.39b)}$$

where the subscripts U and t1 on the tangent vectors are used by the program to identify the user-supplied tangent vectors (record set N16), and where the subscript 1 on the specified flow is used to place the user-supplied specified flow (record set N17) into the first equation.

The upper surface boundary condition equation (B.3.39a) is obtained by applying the general boundary condition, equation (B.3.38), to the upper surface. By defining the two tangent vectors to be equal and of unit magnitude, the specified flow term $\beta_{t1}$ can be determined, for example, by applying either equation (B.3.34) or equation (B.3.35) to the upper surface. The lower surface is assigned the boundary condition of perturbation stagnation, equation (B.3.39b). Using the definition of the doublet strength as the difference between the potential on the upper and lower surfaces, equation (A.2.1b), and using the boundary condition on the lower surface, equation (B.3.39b), gives the relation $\phi_U = \mu$. From this the perturbation velocity on the upper surface satisfies the relation

$$\hat{t}_U \cdot \vec{v}_U = \vec{\nabla}\mu$$

This relation is not used in the boundary condition equations since no singularity parameter would be eliminated by so doing.

### B.3.3.2 Class 3 - Subclass 2 (LOWER)

This boundary condition subclass is the design problem on the lower surface of a thick configuration, with the lower surface wetted by the physical flow. This problem is the same as subclass 1 (UPPER), except that the definition of the upper and lower surfaces, or equivalently the direction of the surface normal vector relative to the physical flow, is reversed. The equations used by the program are

$$\vec{t}_L \cdot \vec{v}_L = -\vec{t}_{t1} \cdot \vec{U}_o + \beta_{t1} \qquad \text{(B.3.40a)}$$

$$\phi_u = 0 \qquad \text{(B.3.40b)}$$

where the subscripts L and t1 on the tangent vectors are used by the program to identify the user-supplied tangent vectors (record set N16), and where the subscript 1 on the specified flow is used to place the user-supplied specified flow (record set 17) into the first equation. By defining the two tangent

vectors to be equal and of unit magnitude, the specified flow can be determined, for example, by applying either equation (B.3.34) or equation (B.3.35) to the lower surface.

B.3.3.3 Class 3 - Subclass 3 (THICKNESS)

This boundary condition subclass is the thickness design problem on an impermeable, thin configuration, figure B.35. This subclass defines equations for thickness design with user-specified pressure coefficient and camber functions. The equations used by the program are

$$\vec{t}_A \cdot \vec{v}_A = -\vec{t}_{t1} \cdot \vec{U}_o + \beta_{t1} \tag{B.3.41a}$$

$$\vec{w}_A \cdot \hat{n} = -\vec{U}_o \cdot \hat{n} + \beta_{n2} \tag{B.3.41b}$$

The first relation is that for average velocity design on a thin configuration. In the case where the two tangent vectors are equal and of unit magnitude, the first relation is obtained by writing equation (B.3.37) for both the upper and lower surfaces, with the same unit tangent vector on both surfaces. These two equations are then added and divided by two to obtain equation (B.3.41a) with the new quantities

$$\vec{v}_A = \frac{1}{2} (\vec{v}_U + \vec{v}_L) \tag{B.3.42a}$$

$$\beta_{t1} = \frac{1}{2} (\beta_{tU} + \beta_{tL}) \tag{B.3.42b}$$

The specified flow can be determined, for example, by applying either equation (B.3.34) or equation (B.3.35), with appropriate notational changes to indicate the upper and lower surfaces. In the case of equation (B.3.34) the relation is

$$\beta_{t1} = V_\infty \left[1 - \frac{1}{4} (C_{pU} + C_{pL})\right] \tag{B.3.43}$$

Only the average of the upper and lower surface pressure coefficients is specified.

The second relation, equation (B.3.41b), is that for a linearized deflection or camber representation on a thin configuration. This relation is used in class 2 boundary conditions subclasses 3 and 5, equations (B.3.19b) and (B.3.21b), and is discussed in section B.3.2.5.

In this subclass the user specifies the average (of the upper and lower surface) properties of a thin configuration. The user specifies (1) the average total tangential velocity (related to the average pressure coefficient) through $\beta_{t1}$ and (2) the average perturbation normal mass flux (related to the average surface camber or deflection) through $\beta_{n2}$. The problem solution gives the normal mass flux difference between the upper and lower surfaces (which equals the source strength). By equations (B.3.24a)

and (B.3.26) this determines the configuration thickness which corresponds to the two sets of data specified by the user.

B.3.3.4 Class 3 - Subclass 4 (CAMBER)

This boundary condition subclass is the camber design problem on an impermeable, thin configuration, figure B.35. This subclass defines equations for camber design with user-specified pressure coefficient and thickness functions. The equations used by the program are

$$\sigma = \beta_{n1} \tag{B.3.44a}$$

$$\vec{t}_D \cdot \vec{\nabla}\mu = \beta_{t2} \tag{B.3.44b}$$

The first relation is that for linearized thickness representation on a thin configuration. This relation is used in class 2 boundary conditions subclasses 4 and 5, equations (B.3.20a) and (B.3.21a), and is discussed in section B.3.2.5.

The second relation is that for difference velocity design on a thin configuration. In the case where the tangent vector has unit magnitude, the second relation is obtained by writing equation (B.3.37) for both the upper and lower surfaces, with the same unit tangent vector on both surfaces. These two equations are then subtracted and the difference in the tangential components of the perturbation velocities replaced by the gradient of the doublet strength to give equation (B.3.44b) with the new quantity

$$\beta_{t2} = \beta_{tU} - \beta_{tL} \tag{B.3.45}$$

The specified flow can be determined, for example, by applying either equation (B.3.34) or equation (B.3.35), with appropriate notational changes to indicate the upper and lower surfaces. In the case of equation (B.3.34) the relation is

$$\beta_{t2} = -\frac{1}{2} V_\infty \ (C_{pU} - C_{pL}) \tag{B.3.46}$$

Only the difference between the upper and lower surface pressure coefficients is specified.

In this subclass the user specifies the difference (of the upper and lower surface) properties of a thin configuration. The user specifies (1) the difference normal mass flux (equal to the source strength and related to the thickness of the configuration) through $\beta_{n1}$ and (2) the difference tangential velocity (related to the difference pressure coefficient) through $\beta_{t2}$. The problem solution gives the normal mass flux average of the upper and lower surfaces. By equations (B.3.24b) and (B.3.27) this determines the configuration camber or deflection which corresponds to the two sets of data specified by the user.

B.3.3.5 Class 3 - Subclass 5 (THICKNESS CAMBER)

This boundary condition subclass is the thickness and camber design problem on an impermeable, thin configuration, figure B.35. This subclass defines equations for thickness and camber design with user-specified pressure coefficient functions. The equations used by the program are

$$\vec{t}_A \cdot \vec{v}_A = - \vec{t}_{t1} \cdot \vec{U}_o + \beta_{t1} \tag{B.3.47a}$$

$$\vec{t}_D \cdot \vec{\nabla}\mu = \beta_{t2} \tag{B.3.47b}$$

The first relation is equation (B.3.41a) of subclass 3 for thickness design. The second relation is equation (B.3.44b) of subclass 4 for camber design. In the case where the three tangent vectors are equal and of unit magnitude, the specified flows are given by equations (B.3.42b) and (B.3.45). The specified flows on the two surfaces can be obtained, for example, by applying either equation (B.3.34) or equation (B.3.35), with appropriatenotational changes to indicate the upper and lower surfaces. In the case of equation (B.3.34) the relations are

$$\beta_{t1} = V_\infty \left[ 1 - \frac{1}{4} (C_{pU} + C_{pL}) \right] \tag{B.3.48a}$$

$$\beta_{t2} = - \frac{1}{2} V_\infty (C_{pU} - C_{pL}) \tag{B.3.48b}$$

Both the average and difference of the pressure coefficients on the upper and lower surfaces are specified.

In this subclass the user specifies the complete pressure coefficient or tangential velocity data for the thin configuration. The problem solution gives both the difference and the average normal mass flux for the upper and lower surfaces. By equations (B.3.24), (B.3.26) and (B.3.27) these determine the configuration thickness and the configuration camber or deflection, respectively, which correspond to the pressure data specified by the user.

B.3.3.6 Class 3 - Subclass 6 (BOTH)

This boundary condition subclass is equivalent to subclass 5. The equations used by the program are

$$\vec{t}_U \cdot \vec{v}_U = - \vec{t}_{t1} \cdot \vec{U}_o + \beta_{t1} \tag{B.3.49a}$$

$$\vec{t}_L \cdot \vec{v}_L = - \vec{t}_{t2} \cdot \vec{U}_o + \beta_{t2} \tag{B.3.49b}$$

The two boundary conditions are obtained directly by applying equation (B.3.38) to the upper and lower surfaces, introducing appropriate notation for the tangent vectors and letting

$$\beta_{t1} = \beta_{tU} \tag{B.3.50a}$$

$$\beta_{t2} = \beta_{tL} \tag{B.3.50b}$$

The subscripts 1 and 2 are used by the program to place the user-supplied specified flows into the proper equation. In the case where the four tangent vectors are equal and of unit magnitude, the specified flows on the two surfaces can be obtained, for example, by applying either equation (B.3.34) or equation (B.3.35). In the case of equation (B.3.34) the relations are

$$\beta_{t1} = V_\infty \left(1 - \frac{1}{2} C_{pU}\right) \tag{B.3.51a}$$

$$\beta_{t2} = V_\infty \left(1 - \frac{1}{2} C_{pL}\right) \tag{B.3.51b}$$

Subclass 5 and subclass 6 boundary conditions are equivalent if the notational differences of the tangent vector coefficients and the specified flows are accounted for. Specifically the average and difference of equations (B.3.49a) and (B.3.49b) for subclass 6, together with the required notational changes, give equations (B.3.47a) and (B.3.47b) for subclass 5. Comparing equations (B.3.50a) and (B.3.50b) with equations (B.3.48a) and (B.3.48b) shows that subclass 6 is appropriate when the pressure coefficients are expressed in terms of upper and lower surface values and subclass 5 is appropriate when the pressure coefficients are expressed in terms of average and difference values.

### B.3.4 Control Points and Boundary Condition Location Points

The boundary condition equations are imposed at the control points of each network. In PAN AIR the control points are located at each panel center, at each network corner point, and at each panel edge mid-point which is on the network edge. (Control points are actually located near, but not exactly at these positions.) Beside the standard control point locations just discussed, "additional" control points can occur at panel corner points on the network edge. These points are introduced at network abutments of the type shown in figure B.36. Control point locations are discussed in detail in Appendix G of the Theory Document.

A maximum of two non-null boundary condition equations can be imposed by the user at each control point. PAN AIR combines these user-specified equations with other equations to give two equations at each control point. This set of equations is identified in the (optional) printout of the DQG module.

Arrays of "boundary condition location points" are defined for each network, with each point corresponding to one boundary condition equation. The number and the locations of the boundary condition location points depend upon the type of flow problem under consideration. Since a network is composed of the superposition of source and doublet distributions, separate arrays are defined for these two distributions. The arrays have standard forms shown in figure B.37. In addition to the arrays shown in figure B.37, a null source (NOS) and a null doublet (NOD) array are used. For example, the

null source array is used in combination with the wake singularity arrays since the wakes are doublet-only networks.

In most applications the PAN AIR user need not be concerned with the boundary condition location point arrays. The arrays are automatically specified by the boundary condition class and subclass for classes 1, 2 and 3. For class 1 and 2 analysis problems on non-wake networks, PAN AIR automatically selects the arrays (SA or NOS, and DA) which correspond to the boundary condition class and subclass. In this case the user need not be concerned with the positions of the boundary condition location points since the arrays involved are symmetric with respect to the network edge numbers. For wake networks the user must locate the points on the proper network edge; for example, for network type DW1 the points should be on the leading edge. For class 3 design problems, PAN AIR automatically selects the arrays, but the user must locate the points on the proper network edges; for design networks the points should usually be on the leading and outboard edges. For boundary condition classes 4 and 5 the user must specify the arrays (using record N11).

PAN AIR has a user-convenience feature (record N12) for relocating the boundary condition location points which occur on the network edges. The default positions of these points shown in figure B.37 are determined by the indexing of the network edges which in turn are determined by the ordering of the network grid points in the input data. The resulting locations of the points can be changed by using record N12, which allows the user to specify the edges to be used for the point locations. Thus the user is not restricted by a requirement on the positions of the boundary condition location points when ordering the network grid points. For example, in the source and doublet design arrays (SD1 and DD1) the network edge boundary condition location points can be placed on any two adjacent network edges by using record N12.

For analysis boundary conditions, the source (SA) and the doublet (DA) distributions have different boundary condition location point arrays as shown in figure B.37. More points are required for the doublet singularities due to their having a higher-order distribution: the doublet singularities have a quadratic variation; the source singularities have a linear variation. Each panel center control point has two non-null boundary conditions. Each edge and corner control point has one non-null boundary condition equation, which is either one of the network boundary conditions or an edge matching condition between network edges or along a free edge. The edge matching condition is discussed in section 8.3.5.

For design boundary conditions, the boundary condition location point arrays for the source (SD1) and doublet (DD1) singularities are identical, except that the doublet array has two more network corner points. For the points on the network edges or corners, the usual boundary conditions are closure, or source and doublet edge matching with abuting networks. There is a basic restriction on the network control point locations in design type boundary conditions: abutting network edges must not have more than one set of boundary condition location points at the abutment. In this case the doublet (or source) edge matching boundary conditions are not sufficient to determine the doublet (or source) strengths at multiple sets of points at the abutment.

For wake networks, two arrays of boundary condition location points are possible. In the first type (DW1), the points are located along edge 1 at all

panel edge mid-points and at the network edge corner points. This array allows the doublet strength to vary in the (nominally) spanwise direction. Since the doublet strength does not vary in the (nominally) streamwise direction, type DW1 networks are usually paneled as shown in figure B.37. In the second type (DW2) a single point is located at the network corner point defined by edges 1 and 4. (By program definition the point is located on edge 1.) Since the doublet strength is constant on the type DW2 network, the networks are usually not divided into panels. The use of wake networks is discussed in sections B.1.2 and B.3.6.

### B.3.5 Closure and Edge Matching Boundary Conditions

Closure and edge matching boundary conditions can be specified by the user. Both conditions are separate from the general boundary condition equation, figure B.25, discussed in section B.3.1. Both are used to define boundary conditions at control points located on network edges, although the application is indirect in the case of the closure condition.

#### B.3.5.1 Closure Condition

The closure condition (record set N14) is the specification of the total normal mass flux passing through a network surface. The general form of the closure boundary condition is

$$\iint_{\text{edge}}^{\text{edge}} \left[ a'_U \left(\vec{w}_U \cdot \hat{n}\right) + a'_L \left(\vec{w}_L \cdot \hat{n}\right) + a'_A \left(\vec{w}_A \cdot \hat{n}\right) + a'_{D\sigma} \right] ds = \beta_C \qquad \text{(B.3.52)}$$

One closure condition applies to one network only; each design network can have its own (independent) closure condition. The closure condition gives one equation for each column of panels (or row of panels, depending upon the user-specified integration direction). It replaces a singularity strength matching boundary condition, usually source strength matching, at the control point located on the matching edge of the design network. The user specifies this matching edge, which is also the lower limit of the integral of equation (B.3.52). The closure condition involves the designated normal mass flux values at all panel center control points in the column. The user specifies the left-hand side coefficients at all panel center control points in the network, and the right-hand side coefficient for each column (and for each solution). The left-hand side coefficients may be zero on some panels, thus restricting the integration range. However, the left-hand side coefficients cannot all be zero for an entire column (or row, depending on the integration direction) of panels, since this would give a singular AIC. The general relation, equation (B.3.52), allows the user to specify non-zero values for both the upper-lower and the average-difference terms. The program converts these to total average-difference terms. The closure condition is discussed in appendix K.4 of the Theory Document.

The closure condition controls the mass flux flowing into or out of a surface. For example, one application would be the requirement that the total mass flux from the upper surface of a network be zero, that is,

$$\iint \vec{w}_U \cdot \hat{n}\, ds = 0 \qquad \text{(B.3.53)}$$

This is applied to each column of panels on the network upper surface. As a consequence the leading and trailing edges of each column of panels on the upper surface will (individually) be on the same mass flux streamline (see section H.2.4 of the Theory Document). Thus if the upper surface is redesigned to obtain a given pressure coefficient, the locations of the leading and trailing edges of the original surface will not be moved. Equation (B.3.53) can be written in the form of the general closure condition, equation (B.3.52). By equation (B.3.8) the total mass flux is the sum of the total onset flow and the perturbation mass flux. Equation (B.3.53) becomes

$$\iint \vec{w}_U \cdot \hat{n}\, ds = \beta_c \qquad \text{(B.3.54a)}$$

$$\beta_c = - \iint \vec{U}_o \cdot \hat{n}\, ds \qquad \text{(B.3.54b)}$$

Equation (B.3.54a) is in the form of equation (B.3.52) with $a'_U = 1$, with the other left-hand side coefficients set to zero, and with the user-specified right-hand side coefficients determined by equation (B.3.54b). (The "volume flow" which is an integral related to that of equation (B.3.54b) is calculated in the CDP module, see section B.4.1.)

In an alternate application, the total mass flux condition, equation (B.3.53), is applied to both the upper and lower surfaces of a thin configuration. Applying the preceding development to the lower surface gives

$$\iint \vec{w}_L \cdot \hat{n}\, ds = \beta_c \qquad \text{(B.3.55)}$$

where the right-hand side coefficient is determined by equation (B.3.54b). Subtracting equation (B.3.55) from equation (B.3.54a) gives the relation

$$\iint \sigma\, ds = 0 \qquad \text{(B.3.56)}$$

where $\sigma = (\vec{w}_U - \vec{w}_L) \cdot \hat{n}$ by equation (A.2.5a). Equation (B.3.56) has the form of the general closure condition, equation (B.3.52), and is the requirement that the total source strength of the network be zero.

Examples of the use of a closure condition in a design problem are given as cases 7 and 8 in the Case Manual.

### B.3.5.2 Edge Matching Boundary Conditions

Edge matching boundary conditions are applied at network abutments to maintain continuity of doublet strength and, in rare cases, source strength. (Within the networks doublet continuity is obtained by the splining method used by PAN AIR.) The continuity of doublet strength eliminates spurious line vortex terms which can cause numerical problems. Edge matching boundary conditions are described in detail in appendix F of the Theory Document.

In the PAN AIR program edge matching boundary conditions are developed in two parts. First, network edge abutments are identified. Second, a doublet strength matching condition is specified at the network abutments.

Network edge abutments are identified either by user specification or by an automatic abutment search procedure. The user specification (using records GE1 to GE4) suppresses the automatic abutment search. This approach is usually unnecessary, but allows the user to control directly the abutment specification. The user is also allowed to specify "smooth abutments" between two networks. In this case doublet continuity is obtained by a splining method rather than the edge matching boundary condition. The advantage of this feature is economy, since the singularity parameters along the abutting network edges are not required, resulting in fewer unknown singularity parameters. The smooth abutment procedure should only be used if the two networks abut to form a continuously smooth surface, since the splining method assures the continuity of both the doublet strength and its gradient.

The automatic network abutment search procedure is based upon the locations of the network edges and a user-specified geometric tolerance distance (record G7). The automatic abutment search occurs in two steps. In the first step the program searches each network edge for pairwise abutments, which occur if all or part of the edge of one network lies within the user-specified tolerance distance of two adjacent panel corner points of an edge of a second network. An example of three pairwise abutments involving the same two network edges is shown in figure B.38. In the second step the program reduces the list of pairwise abutments into a non-redundant list of program-generated abutments.

The abutments have the following program restrictions. Let NN be the number of network edges (all edges, accounting for planes of symmetry) in an abutment. Then NN must be less than or equal to 5 for each abutment. Also, let NA be the number of abutments containing the same network edges. For example, NA = 3 for the two network edges shown in figure B.38. Then the product (NN·NA) must be less than or equal to 10 for each set of abutments containing the same network edges.

The program selects a single "matching edge" from the several edges in an abutment in order to apply the edge matching boundary condition. The selection procedure is automatic; the user is spared the decision of selecting a matching edge. The program uses several criteria for the selection, in the following order of priority. First, in doublet design and wake networks, figure B.37, the network edge with boundary condition location points is selected as the matching edge with the doublet matching condition applied at those points. Second, if the abutment is a supersonic edge, the leading edge of the most "downstream" network is selected as the matching edge. Third, the most densely panelled edge is selected as the matching edge.

A related program feature is the addition of "gap-filling" panels. These panels, which have constant doublet strength, insure doublet strength continuity across significant gaps (or overlaps) between abutting network edges. The method of introducing gap-filling panels is shown in figure B.39, which is an example of two abutting network edges with significant gaps. The program first defines a preliminary set of panels in the gap(s) between the network edges with their panel corner points located to coincide with the panel corner points on both network edges. Gap-filling panels are selected

from this set by the criterion that at least three edges of a panel must be longer than the user-specified tolerance distance (record G7). This criterion eliminates the possibility of very small gap-filling panels. The corresponding gaps are left as voids in the configuration. (Note that the gap-filling panel procedure is automatic; the only control the user has is in the specification of the tolerance distance, record G7, and the geometry of the network edges.) Boundary conditions are then applied which insure doublet strength continuity between the abutting network edges. Gap-filling panels are discussed in detail in appendix F.4 of the Theory Document.

Once the network abutments have been determined, a doublet strength matching condition is specified at the abutments. (Source strength matching can also be specified, but the present discussion covers only the more important doublet matching condition.) The edge matching boundary condition, which insures continuity of doublet strength at an abutment, has the general form

$$\sum_{i=1}^{n} s_i \mu_i = 0 \qquad \text{(B.3.57)}$$

where n is the number of edges in the abutment and $s_i = \pm 1$ is determined by the direction of the panel normal. If there are only two network edges in an abutment, then equation (B.3.57) requires that the doublet strengths at the two edges be equal. An example of doublet strength matching at the abutment of three networks is shown in figure B.40. To apply equation (B.3.57) in the general case, the program selects one edge to be the "matching edge" of the abutment. Then the doublet strength matching condition is applied at the endpoints of the abutment and at all panel edge midpoints of the matching edge. The doublet strength matching then occurs along the entire abutment due to the PAN AIR splining technique.

The PAN AIR user can specify a "no doublet edge matching" condition (record N13) at a network edge. This suppresses the automatic doublet edge matching condition. This capability allows the introduction of doublet strength discontinuities of specified network edges.

### B.3.6 Considerations of Modeling and Boundary Condition Usage

Several examples of the modeling of physical configurations and shear layers, together with the development of the associated boundary condition equations, are discussed in this section. The modeling examples show some of the requirements for the proper specification of networks, particularly wake networks. In some cases the associated boundary conditions have non-standard forms which required the use of class 4 (or class 5) boundary conditions.

#### B.3.6.1 Wake Network Modeling

A primary source of error in wake modeling is failure to maintain continuity of wake networks in regions where the physical situation demands continuity. This type of error usually results in solutions which are grossly incorrect! Perhaps the best way to avoid such errors is (1) to define clearly

the true physical structure of the flow, and (2) to examine each and every free edge of every wake network from the point of view of positively determining that the resultant solution will indeed correspond to the true physical flow.

The most common error of this type has been failure of a user to specify that the inboard part of a wake trailing downstream from a wing must abut the body. Consider the physical problem of a lifting flow past the a wing/body combination as shown in figure B.41a. A proper simulation of the physics of the flow consists of the boundary condition of no flow through the solid surfaces, a Kutta condition imposed along the wing trailing edge, and a wake simulation comprised of a type DW1 network with panel edges aligned with the assumed positions of the wake streamlines. The physics of the situation demands that the inboard edge of the wake shed from the wing/body intersection wets the body surface in the downstream direction until encountering the symmetry plane. The numerical model must do likewise.

If the user errs and leaves a gap between the wake edge and the body, the resultant boundary value problem will still be well-posed and the program will execute, but the results will bear little resemblance to the physical situation. The resultant solution will be one in which the circulation about a contour surrounding the wing root, figure B.41b, will be zero. (This can be easily seen from the fact that the contour line passes through the erroneous gap between the body and wake, and therefore crosses no doublet sheet. The circulation about any closed contour not crossing a doublet sheet must be zero.)

A convenient "fix" for closing an erroneous gap between a wing wake and body is to span the gap with another network. A type DW2 (constant doublet strength) wake network can be used for this purpose. An example is shown in figure 3.6. The presence of such a wake network in the network/panel model is critical for good modeling, but the exact location of the inboard wake network is usually of secondary importance.

Another example of how the requirement for wake continuity affects wake modeling is shown by the wake of the flapped configuration of figure 2.3b. Here a deflection of the trailing edge flap causes a vertical separation between the edges of the wake networks trailing from the wing and the deflected flap. Continuity of the wake is maintained by adding vertical wake networks (type DW1) which connect the horizontal wake networks and abut the side edges of the wing and flap which are exposed by the flap deflection. (One possible model of this configuration is given in case 6 of the Case Manual.)

### B.3.6.2 Abutment only at Network Edges

Networks must always satisfy the requirment that their abutments occur only at network edges. This requirement must be considered when dividing a configuration into networks. An example of this is shown in figure 3.6. Here a wake network (type DW2) abuts the body. This requires that the associated body networks have edges at this abutment. (The body networks must also have edges at the plane of symmetry where they abut their image networks.) This requires the user to define one set of networks for the upper body and another

set for the lower body. These two sets then have common abutments with themselves and the DW2 wake network. Further, if the position of the wake network edge were changed, then the body networks also must be changed to account for the new abutment locations. (The PAN AIR update capability can be used to reduce the cost of this operation.)

Another example of the network edge abutment requirement is shown in figure B.42. Here a wake which is shed from a wing intersects a twin vertical tail. The requirement here is that the wake and vertical tail networks must abut at their edges. One way of satisfying this requirement is shown in figure B.42a. Behind the wing two wake networks are defined, with their leading edges each abutting part of the wing trailing edge. The inboard wake network has the outboard side edge CDEF where it abuts the outboard wake network along CD, abuts inboard networks of the vertical tail along DE, and abuts the outboard wake network and the wake networks of the vertical tail along EF. The vertical tail networks must be defined such that they have edges along DE where the wake networks abut the vertical tail networks. Figure B.42b shows the paneling requirements for the two wing wake networks. The inboard and outboard wing wake networks must be paneled such that points D and E are panel corner points. Further paneling of the wing wake networks may be required for them to match the geometry of the vertical tail along DE. Note that the vertical tail location must be considered when paneling the wing networks(s) since point C must be a panel corner point. (Point C is not required to be a network corner point of the wing network(s).)

### B.3.6.3 Wake Entrainment and Efflux

The modeling of shear layers which entrain or expell mass flux introduces special considerations. With entrainment/efflux simulation a standard "wake" network can not be used. An example is shown in figure B.43. The shear layer of figure B.43 can be modeled as follows. The entrainment is accounted for by a condition of specified total normal mass flux on the outer surface of the network (here assumed to be the upper surface). The boundary condition equation is

$$\vec{W}_U \cdot \hat{n} = \beta_n \tag{B.3.58a}$$

where $\beta_n$ is the user-supplied normal mass flux of the entrainment or efflux.

With the mass flux entrainment shown in figure B.43b, the $\beta_n$ term of equation (B.3.58a) is negative. The boundary condition equation is put into the standard form of figure B.25 by using equation (B.2.6) to write the total mass flux as the sum of the total onset flow velocity and the perturbation mass flux.

$$\vec{w}_U \cdot \hat{n} = - \vec{U}_o \cdot \hat{n} + \beta_n \tag{B.3.58b}$$

For the interior region Dirichlet boundary conditions are used to insure a properly posed problem there. Since the lower surface is exposed to the interior region, the second boundary condition is

$$\phi_L = 0 \qquad \text{(B.3.58c)}$$

This boundary condition also applies to the entire surface exposed to the interior region, including the surface of network AB at the nacelle exit. The wake entrainment/efflux problem can thus be modeled with standard boundary conditions: class 2, subclass 1.

Several points are noted in the model of figure B.43. First, the model is not a shear layer since a composite network with non-zero source strength, rather than a wake network, is used. Second, the mass flux which flows into the network upper surface, figure B.43b, is absorbed by the network source strength so that no mass flux is passed into the unperturbed interior domain. Third, the model can be used to simulate the exhaust mass flow. The user must supply the location of the exit tube and its entrainment/efflux rate. With this information the effects of the exhaust flow upon the exterior domain are contained in the simulation. The effects are not described in the interior domain, but this is not important since the interior domain is isolated from the exterior domain by the use of the composite network. Fourth, the network AB could be removed, in which case the interior domain would also include the interior region of the nacelle.

### B.3.6.4 Boundary Layer Displacement and Wake Simulation

The user has several choices in defining a model to simulate boundary layers and wakes. Two possible models for the boundary layer and wake of an airfoil are shown in figure B.44.

Figure B.44a shows the use of linearized modeling for the boundary layer displacement effect. The airfoil is modeled as a thick configuration with the boundary layer modeled by a specified normal mass flux emitted by the airfoil network. This is the same problem as linearized modeling of surface deflection, equations (B.3.7) to (B.3.10). The appropriate boundary condition equations are those for class 2, subclass 1 or 2 (depending upon whether the upper or lower network surface is wetted by the physical flow field). The wake is modeled by a single network (type DW1) with standard boundary conditions of zero source strength throughout and constant doublet strength in the streamwise direction.

Figure B.44b shows an "exact" displacement surface model. Networks are defined at the displacement surface, so no specfied normal mass flux is required to simulate the difference between the positions of the network and the boundry layer. The networks have impermeable surface boundary conditions: class 1, subclass 1 or 2 for the "airfoil" networks, and class 1, subclass 4 (zero source strength and constant doublet strength in the steamwise direction) for the pair of wake networks. The configuration has an additional network AB which separates the domains enclosed by the airfoil and wake networks. Network AB requires two boundary conditions. One is the extension of the perturbation stagnation condition on the interior of the airfoil. This gives the equation (noting the direction of $\hat{n}$ in figure B.44b)

$$\phi_L = 0 \qquad \text{(B.3.59a)}$$

The second boundary condition requires consideration of the flow at points A and B. As the external flow moves from the airfoil to the wake boundary, the flow should not cross the wake surface. This is accomplished by requiring zero total tangential mass flux on the upper surface of network AB. The appropriate boundary condition is (see appendix H.3 of the Theory Document)

$$\bar{\Phi}_U = 0$$

Note that this does not preclude flow normal to the upper surface of network AB. This relation can be written in the form of equation (B.3.2),

$$\phi_U = - \vec{U}_\infty . \vec{\Psi} \qquad \text{(B.3.59b)}$$

where $\vec{\Psi} = (x/s\ \beta^2,\ y,\ z)$.

The preceding boundary condition equations can be written in a more efficient form. Any independent linear combination of the two equations is equivalent to the original two equations. The most efficient combination is that which determines one or both singularity strengths. Noting that the doublet strength is the difference of the perturbation potential on the two surfaces, equation (A.2.1b), equation (B.3.59a) is subtracted from equation (B.3.59b) to give

$$\phi_U - \phi_L = \mu = - \vec{U}_\infty \cdot \vec{\Psi} \qquad \text{(B.3.59c)}$$

The resulting boundary conditions on AB are equations (B.3.59a) and (B.3.59c). These can be specified by using class 4 boundary conditions (record N9).

The method for simulation of boundary layer displacement can also be applied to the simulation of separated flows, figure 2.3c and reference B.6.

### B.3.6.5 Nacelle Modeling in Subsonic Flow

The modeling of the inflow and outflow from a nacelle introduces some special modeling considerations. An example is shown in figure B.45. The boundary condition of zero perturbation potential has been imposed everywhere on the interior surface. As explained in section A.3, this gives a Dirichlet problem in the interior region, which is well-posed. (For convenience the network upper surfaces are defined to be those wetted by the physical flow.)

The network AD representing the nacelle inlet has standard class 2, subclass 1, boundary conditions

$$\sigma = - \vec{U}_0 \cdot \hat{n} + \beta_n$$

$$\phi_L = 0$$

where $\beta_n$ is the user-specified normal mass flux issuing from the network. For inflow $\beta_n$ will be negative since the normal vector points outward.

The network(s) AB and CD representing the external boundary of the nacelle have class 1, subclass 1 boundary conditions appropriate for an impermeable boundary surface. The wake network(s) (type DW1) allow the doublet strength to vary circumferentially. The doublet strength is determined by the strength matching condition at the wake leading edge. The wake network closes upon itself (or its image(s) in plane(s) of symmetry) circumferentially. In theory it forms, together with network BC, a closed interior region aft of the nacelle outlet. In practice the wake network has a finite streamwise length, extending far enough so that its truncation does not significantly affect the flow at the nacelle. (The downstream end of the wake is left open.) The wake position must be specified by the user. If required by the physical flow field, an entrainment flow can be specified, in which case the modeling associated with figure B.43 should be used.

For network BC, at the aft end of the nacelle, the proper upper surface boundary condition is zero total tangential mass flux. This insures that there is no flow through the wake network at points B and C. The boundary condition equations are

$$\phi_L = 0$$

$$\bar{\Phi}_U = 0$$

These boundary conditions are the same as equations (B.3.59) used in the previous example.

In the above model, the user cannot specify an exhaust mass flow. This would result in an ill-posed problem in the interior region aft of the nacelle. Instead, the total potential boundary condition is used. The exhaust mass flux is obtained as part of the problem solution. The user can influence its value only indirectly through specification of the wake network location.

A study of subsonic flow nacelle modeling using panel methods is given in reference B.7.

### B.3.6.6 Nacelle Modeling in Supersonic Flow

Special considerations are required for nacelle modeling in supersonic flow. The primary requirement is to eliminate internal waves which can cause serious numerical problems. Superinclined panels are used to seal off the inlet and, if required, to specify the exhaust flow.

An example of the combined use of composite panels and superinclined panels is shown in figure B.46. A superinclined network is used to seal off the engine inlet. Two independent boundary conditions must be specified on the downstream surface of this network. Since that surface is exposed to the

interior domain, the proper boundary conditions are the specification of zero perturbation potential and the specification of zero normal velocity. Another superinclined panel is used at the engine exhaust. Again, two boundary conditions must be specified on the downstream surface. Similar boundary conditions are used, except that the true physical (non-zero) value of the normal velocity is specified. (For both superinclined networks, the boundary condition equations would be specified by using class 4 boundary conditions.) Underexpanded and overexpanded nozzle flows can be simulated. Elsewhere on the vehicle, standard impermeable thick configuration boundary conditions (class 1, subclass 1 or 2) are specified. Wake networks are added aft of the engine exhaust. (Note that the boundary value problem in the region bounded by the engine exhaust network and the wake networks is well-posed, see item 3 in section A.3.4.1.)

In modeling an engine inlet in supersonic flow basically two models are available. Both are shown in figure B.47. In the first model, figure B.47a, a superinclined network AB is used to seal off the inlet. Again the superinclined network has two boundary conditions on the downstream surface. The superinclined network "swallows" whatever mass flux runs into it, providing undisturbed freestream conditions on its downstream side. Also, since the superinclined network cannot affect the upstream flow, it has no influence upon the incoming mass flux. Consequently the user cannot specify that mass flux.

In the second model, figure B.47b, a subinclined network AB is used at the engine inlet. In this case one boundary condition is specified on the upstream surface of the network. The user can thus specify the mass flux at the engine inlet.

## B.4 Flow Field Calculations

The solution of the matrix equation (A.3.5) or (B.2.4) gives the array of singularity strength parameters. From these the program computes the source and doublet singularity distributions on the networks and then the properties of the flow field. In this section the "post-solution" calculations of the flow field available in PAN AIR are described. First, the calculations of the velocity field are described. Second, the calculation of the pressure coefficients and related results is described. Finally, the calculation of the force and moment coefficients is described.

### B.4.1 Velocities

The velocity of the flow field at a network surface can be calculated by two methods: (1) using the boundary condition equations and (2) using the velocity influence coefficients. The velocity calculations are discussed in detail in appendix N.1 of the Theory Document.

The first method (record G9, option BOUNDARY-CONDITION) calculates the perturbation velocities at a network surface directly from the boundary condition equations if possible. The tangential velocity vector and the normal mass flux component are calculated, which in turn determine the velocity vector. The tangential velocity is calculated from the velocity potential function at the network surface. The potential is determined directly from the boundary conditions if possible. For example, if a zero value of perturbation potential ("perturbation stagnation") is specified on one surface (record N10, options LOWER and UPPER-SURFACE-STAGNATION) then the potential on the opposite surface is known from the doublet strength, which equals the potential difference between the upper and lower surfaces. Otherwise (record N10, option NONSTAGNATION) the potential is calculated from the potential influence coefficient matrix. The method of calculating the normal mass flux also depends on the boundary condition equations. If the perturbation stagnation condition is specified on one surface, then the normal mass flux is determined directly since the normal mass flux difference between the upper and lower surfaces equals the source strength. If the boundary conditions do not specify stagnation on one of the surfaces, other methods must be used. If the boundary condition specifies the normal mass flux, then that is used directly. Otherwise the normal mass flux is computed from the product of the conormal vector and the velocity influence coefficient matrix.

The normal velocity component is then calculated from the known tangential velocity vector $\vec{v}_t$ and normal mass flux component $w_n$.

$$v_n = \frac{w_n - \vec{v}_t \cdot \hat{n}}{\hat{n} \cdot \tilde{n}} \qquad \text{(B.4.1)}$$

where n and n are the normal and conormal vectors (see section A.2). The perturbation velocity is determined by using this relation and the known tangential velocity.

The second method (record G9, option VIC-LAMBDA) calculates the perturbation velocity directly from the velocity influence coefficient matrix, [VIC].

$$\{v\} = [VIC]\ \{\lambda\} \qquad (B.4.2)$$

This method is relatively expensive since it requires the calculation and storage of the velocity influence coefficient matrix.

The preceding methods give the perturbation velocity at the network control points and at the panel enriched grid points. PAN AIR also calculates the velocity at arbitrary user-specified points (record SF4b) by interpolating the values calculated at the grid points.

The total velocity is calculated as the sum of the total onset flow velocity and the perturbation velocity, that is,

$$\vec{V} = \vec{U}_o + \vec{v} \qquad (B.4.3)$$

This velocity, possibly modified by the corrections described below, appears in the (optional) output of the PDP module.

Two empirically-based velocity corrections are available in PAN AIR. These corrections can be important where the flow properties predicted by linear theory are not accurate, for example, in the neighborhood of a stagnation point where the perturbation velocities are not small. Both are referred to as stagnation-to-ambient (SA) velocity corrections. Both corrections are dependent upon the freestream Mach number and become zero with zero Mach number, so are unnecessary in incompressible flow. The velocity corrections are discussed in detail in appendix N.3 of the Theory Document.

The first correction (record G11, option SA1) is used to correct the velocity at a blunt leading edge of thick unswept wings or of flow-through nacelles. The correction is applied to $v_c$, the perturbation velocity component in the compressibility direction $\hat{c}_o$, that is,

$$v_c = \vec{v} \cdot \hat{c}_o$$

The linear formulation assumes that the magnitudes of the perturbation velocity components are much less than the magnitude of the uniform onset flow. This assumption is violated near a stagnation point where the perturbation velocity is of the same order as the onset flow velocity. The $v_c$ predicted by linear theory is thus corrected if its value is negative. The correction is based on the corresponding perturbation mass flux $w_c$ calculated by linear theory, since the mass flux satisfies the boundary conditions. The corrected perturbation velocity component is computed from the perturbation mass flux, that is, for the components in the compressibility direction,

$$(v_c)_{corrected} = \frac{\rho_\infty}{\rho} w_c \qquad (B.4.4)$$

The density ratio is determined from the isentropic relation.

$$\frac{\rho}{\rho_\infty} = \left[1 + \frac{\gamma-1}{2} M_\infty^2 \left(1 - \frac{V^2}{V_\infty^2}\right)\right]^{1/\gamma - 1} \qquad \text{(B.4.5)}$$

where $\gamma$ is the ratio of specific heats and $M_\infty$ is the Mach number of the uniform onset flow. Note that the total velocity in equation (B.4.5) includes the corrected $v_c$, so an iterative solution procedure is required.

The second correction (record G11, option SA2) is used to correct the velocity for predicting the outer flow in a boundary layer analysis. It is used for thick wings or wing-like configurations. Again, the correction is based on the mass flux calculated by linear theory since the mass flux satisfies the boundary conditions. In this case the correction is based on making the total velocity vector aligned with the total mass flux vector. If the perturbation velocity component in the compressibility direction $v_c$ is non-negative, then the direction of the corrected velocity is calculated from the relation

$$\vec{V}_{\text{corrected}} = \frac{|\vec{V}|}{|\vec{W}|} \vec{W} \qquad \text{(B.4.6)}$$

where $|\vec{V}_{\text{corrected}}| = |\vec{V}|$, that is, the correction changes the direction but not the magnitude of the total velocity. If the perturbation velocity component in the compressibility direction $v_c$ is negative, then the correction changes both the direction and the magnitude of the total velocity. Using the calculated mass flux, the corrected total velocity is computed from the relation

$$\vec{V} = \frac{\rho_\infty}{\rho} \vec{W} \qquad \text{(B.4.7)}$$

where the density ratio is calculated from the linear relation

$$\frac{\rho}{\rho_\infty} = 1 - M_\infty^2 \frac{v_c}{V_\infty} \qquad \text{(B.4.8)}$$

The final values of the flow velocity are obtained from equation (B.4.3) with the optional velocity corrections described above. The resulting flow velocity is optionally printed in the PDP module and is used in the calculation of pressure coefficients described in the next section. The optional printed output of the PDP module includes the total mass flux which is calculated from the relation (see section B.2.2)

$$\vec{W} = \vec{U}_0 + \vec{w} \qquad \text{(B.4.9)}$$

The surface vorticity vector $\vec{\gamma}$ is calculated from the relation

$$\vec{\gamma} = \hat{n} \times \vec{\nabla}\mu \qquad \text{(B.4.10)}$$

The angle between the average total velocity and the surface vorticity is optionally calculated and printed for wake networks. This angle is a measure of whether the user-specified wake position is physically reasonable. If so,

the angle will be small everywhere on the wake network. This implies that the average (of the upper and lower surface values) total velocity (1) is in the plane of the network, that is, the normal velocity component is small, and (2) is normal to the user-specified direction of doublet strength variation. (Note that the surface vorticity vector is perpendicular to the normal vector and to the doublet gradient vector.)

PAN AIR also calculates geometric properties of the networks and panels, and some other quantities related to the flow field. One is the normal component of the uniform onset flow velocity (the "volume flow")

$$\iint \vec{U}_\infty \cdot \hat{n} \; ds$$

where the integration can cover individual panels, columns of panels, a network or a collection of networks. This integral (calculated and printed in the CDP module) is related to that used in specifying the closure condition, equation (B.3.54b).

### B.4.2 Pressure Coefficients and Associated Quantities

The pressure coefficients on the network surfaces are calculated from the known velocity field. In PAN AIR the pressure coefficients can be calculated from the relation for the isentropic flow of a perfect gas and from several approximations based upon assumptions of small perturbation quantities. Several associated quantities can be calculated which are related to the local flow properties and consequently provide an indication of the validity of the calculated pressure coefficients.

The definition of the local pressure coefficient is

$$C_p = \frac{p - p_\infty}{1/2 \; \rho_\infty \; U_\infty^2} \qquad \text{(B.4.11)}$$

where the $\infty$ subscript refers to conditions in the undistributed flow. The pressure coefficient has several values since each network has both upper and lower surfaces. Using record G8 or record SF5, the pressure coefficient on one or both surfaces, the pressure difference and the average pressure of the two surfaces can be calculated.

To calculate the pressure coefficients, the total velocity is calculated from the velocity of the undisturbed flow field and the perturbation velocity. Since several approximations can be used in defining the undisturbed velocity field (see section B.2.2), corresponding options can be used to define the total velocity. The relation for the total velocity is

$$\vec{V} = \vec{V}_\star + \vec{v} \qquad \text{(B.4.12a)}$$

where $\vec{V}_\star$ is the velocity of the undisturbed flow field as specified by one of three options (record G10):

$$\vec{V}_* = \begin{cases} \vec{U}_\infty & \text{UNIFORM-ONSET-FLOW} \\ |\vec{U}_0| \dfrac{\vec{U}_\infty}{|\vec{U}_\infty|} & \text{TOTAL-ONSET-FLOW} \\ |\vec{U}_\infty| \hat{c}_0 & \text{COMPRESSIBILITY-VECTOR} \end{cases} \qquad \text{(B.4.12b)}$$

To calculate the pressure coefficients, the incremental onset flow velocity $\Delta\vec{V}$ (which includes both the rotational and local onset flows) is separated from the total velocity. The effect of the incremental onset flow is introduced into the pressure coefficients in terms of the quantity $\Delta E$, the energy per unit mass added to the flow by the incremental onset flow. In PAN AIR (see appendix N of the Theory Document).

$$\Delta E = (\vec{U}_\infty + \frac{1}{2}\Delta\vec{V}) \cdot \Delta\vec{V} \qquad \text{(B.4.13)}$$

A program option (record G10 or record SF7) allows the incremental onset flow to be deleted in calculating the pressure coefficients.

Using the relations for the isentropic flow of a perfect gas (see appendix N of the Theory Document), the pressure coefficient is

$$C_p = \frac{2}{\gamma M_\infty^2}\left\{\left[1 + \frac{\gamma-1}{2} M_\infty^2 \left(1 - \frac{V^2 - 2\Delta E}{U_\infty^2}\right)\right]^{\gamma/\gamma-1} - 1\right\} \qquad \text{(B.4.14)}$$

where $\gamma$ is the ratio of specific heats and $M_\infty$ is the Mach number of the uniform onset flow. Several related quantities, which indicate possible limitations of the potential flow solution, are also calculated. The pressure coefficient at the vacuum condition is

$$C_{pv} = -\frac{2}{\gamma M_\infty^2} \qquad \text{(B.4.15)}$$

This is the minimum allowable value of the pressure coefficient on a surface. If lower values are calculated, the pressure coefficient is set equal to its vacuum value. The maximum speed, which corresponds to the vacuum condition, is

$$\frac{V_m}{U_\infty} = \sqrt{1 + \frac{2}{(\gamma - 1)M_\infty^2} + \frac{2\Delta E}{U_\infty^2}} \qquad \text{(B.4.16)}$$

The critical speed, which corresponds to a locally sonic flow, is

$$V_{cr} = \sqrt{\frac{\gamma-1}{\gamma+1}}\, V_m \qquad \text{(B.4.17)}$$

This quantity is important in the interpretation of the calculated velocities, since the linearized potential flow solution is not valid if the local flow speed is close to the critical speed.

Figure B.48 lists the relations for the pressure coefficient, the local Mach number, and the critical pressure coefficient (that is, at the sonic condition). Relations are listed for isentropic flow and for several approximations to the isentropic relations. To develop the approximations, the perturbation velocity and the local onset flow velocity are expressed in components parallel and perpendicular to the preferred direction, which is the direction of the undisturbed flow velocity of equation (B.4.12b).

$$\vec{v} = (u,v,w) \tag{B.4.18a}$$

$$\Delta \vec{V} = (\Delta U, \Delta V, \Delta W) \tag{B.4.18b}$$

The u and $\Delta U$ components are in the preferred direction, which can be that of either the uniform onset flow (defined by $\alpha$ and $\beta$) or the compressibility vector (defined by $\alpha_c$ and $\beta_c$ ). Since PAN AIR allows a linearized analysis with different directions for these two vectors, the user can select the preferred direction (using record G10 or record SF7) to be used in the computation of the flow velocities and pressure coefficients. If the direction of the uniform onset flow is selected, the user has the option of either including or excluding the incremental onset flow terms ($\Delta\vec{V}$) in the pressure coefficient and local Mach number relations.

Under the assumption of small changes from the uniform onset flow, the ratio of the velocity components of equations (B.4.18a) and (B.4.18b) to the uniform onset flow are assumed to be of first order. The linear approximation, figure B.48, is obtained by expanding the isentropic relation and retaining only first-order terms. The second-order approximation is obtained by retaining the first and second-order terms. The reduced second-order approximation is obtained by deleting the Mach number dependent term in the second-order approximation, where the deleted term was assumed to be negligible in the derivation of the Prandtl-Glauert equation. For incompressible flow the reduced second-order approximation is equivalent to the isentropic relations, but avoids singularities at zero Mach number. The slender body approximation is obtained from the second-order relation by omitting the second order terms in u and $\Delta U$; the relations are first- order for the flow in the preferred direction, but retain second-order terms in the transverse directions. This approximation is used in the analysis of flow over axially symmetric or elongated bodies.

The preceding development of the pressure coefficient defined by equation (B.4.11) breaks down when the uniform onset flow velocity is zero. In this special case the user can specify another reference velocity $U_{ref}$ (record G14 or record SF9) for the pressure coefficient calculations. The resulting pressure coefficient relation is

$$C_p = - \frac{V^2}{U_{ref}^2} \tag{B.4.19}$$

## B.4.3 Force and Moment Coefficients

The force and moment coefficients are calculated from the pressure coefficients and the flow properties on the network surfaces. The first step is the calculation of the force and moment integrals, which for a network surface are

$$\vec{I}_F = - \iint \left[ C_p \hat{n}_s + \frac{2\vec{V}\,(\vec{W} \cdot \hat{n}_s)}{U_\infty^2} \right] ds \qquad \text{(B.4.20a)}$$

$$\vec{I}_M = - \iint \vec{Q} \times \left[ C_p \hat{n}_s + \frac{2\vec{V}(\vec{W} \cdot \hat{n}_s)}{U_\infty^2} \right] ds \qquad \text{(B.4.20b)}$$

where $\hat{n}_s$ is a normal vector pointing outward from the surface and $\vec{Q}$ is a point on the surface. (For example, $\hat{n}_s = -\hat{n}$ for the lower surface of a network.) The first term of the force integral gives the force resulting from the pressures acting on the surface. The second term is a "momentum transfer" term which gives the contribution from the velocity and normal mass flux at the surface. Since the normal component of the mass flux is zero at the control points of an impermeable surface, the second term will be relatively small for an impermeable surface. (Evaluation of the force and moment integrals is discussed in appendix O of the Theory Document.)

The computation options available for the pressure coefficient are also available for the force and moment coefficients: different pressure coefficient rules, different surfaces of a network (upper, lower, difference), and so forth. Also, the user has the option of either including (record FM8, option MOMENTUM-TRANSFER) or omitting (program default) the momentum transfer terms.

The surface forces and moments can have additional contributions from discrete edge forces (record FM9). These arise in the use of linear theory for thin configurations because of unrealistic singularities of the flow field which are predicted by the linear analysis (see section O.31 of the Theory Document). The edge force occurs at sharp edges of thin surfaces, either in subsonic flow or on subsonic edges in supersonic flow. A numerical procedure is available in PAN AIR for calculating the edge forces. The procedure uses the general form of the velocity function at the leading edge which is predicted by classical thin wing theory. The specific velocity function is obtained by an extrapolation of the velocity values calculated at interior network points. The edge forces are then calculated from the known velocity function. The procedure is described in appendix O of the Theory Document.

Another type of singularity occurs at blunt edges of thick surfaces, the predicted singularity being caused by the unbounded value of the surface slope. For thick surfaces the singularity problem should be handled by one of the velocity corrections described in section B.4.1 and not by an edge force calculation. Conversely, for thin surfaces the singularity problem should be handled by an edge force calculation (record FM9).

The force and moment integrals are calculated in the reference coordinate system. The force and moment coefficients are obtained from the integrals by introducing user-specified reference parameters (records FM2 and FM11) and a user-specified moment reference point (record FM3).

$$\{\vec{C}_F\} = \frac{1}{SR} \{\vec{I}_F\} \tag{B.4.21a}$$

$$\{\vec{C}_M\} = \frac{1}{SR} \begin{bmatrix} \frac{1}{BR} & 0 & 0 \\ 0 & \frac{1}{CR} & 0 \\ 0 & 0 & \frac{1}{BR} \end{bmatrix} \{\vec{I}_M - \{\vec{R}_o \times \vec{I}_F\}\} \tag{B.4.21b}$$

where SR is the area reference parameter, BR is the span reference parameter, CR is the chord reference parameter and $\vec{R}_o$ is the moment reference point.

The moment coefficient can also be expressed with respect to an alternate reference axis (record FM10). This capability can be used, for example, to calculate a hinge moment on a control surface. The resulting moment coefficient is the component of the vector coefficient, equation (B.4.21b), in a user-specified direction.

The force and moment coefficients calculated in the reference coordinate system (RCS) can be transformed (as user-specified options, record FM3) to components in three other coordinate systems:

1. The (wind-tunnel) stability axis system (SAS)
2. The wind axis system (WAS)
3. A body axis system (BAS).

The components in each of these axis systems can be obtained by application of a coordinate transformation matrix $\Gamma$ which accounts for the rotations of the coordinate axes. For any vector $\vec{r}$, the components ($r_{xo}$, $r_{yo}$, $r_{zo}$) in the reference coordinate system can be transformed to the components ($r_{x'}$, $r_{y'}$, $r_{z'}$) in another axis system by the relation

$$\begin{Bmatrix} r_{x'} \\ r_{y'} \\ r_{z'} \end{Bmatrix} = [\Gamma] \begin{Bmatrix} r_{xo} \\ r_{yo} \\ r_{zo} \end{Bmatrix} \tag{B.4.22a}$$

The stability axis system is obtained from the reference coordinate system by a rotation equal to ($-\alpha$) about the $y_o$-axis, in which case

$$\Gamma_{SAS} = \begin{bmatrix} \cos\alpha & 0 & \sin\alpha \\ 0 & 1 & 0 \\ -\sin\alpha & 0 & \cos\alpha \end{bmatrix} \tag{B.4.22b}$$

The wind axis system is obtained from the reference coordinate system by two rotations: a rotation equal to $(-\alpha)$ about the $y_0$-axis followed by a rotation equal to $(-\beta)$ about the new position of the $z_0$-axis. In this case

$$\Gamma_{WAS} = \begin{bmatrix} \cos\alpha\cos\beta & -\sin\beta & \sin\alpha\cos\beta \\ \cos\alpha\sin\beta & \cos\beta & \sin\alpha\sin\beta \\ -\sin\alpha & 0 & \cos\alpha \end{bmatrix} \qquad \text{(B.4.22c)}$$

With this transformation the $x_0$-axis of the wind axis system is in the same direction as the uniform onset flow, see section B.2.2. Also, the two rotations can be interpreted as two transformations in sequence: the first rotation transforms from the RCS to the SAS; the second rotation transforms from the SAS to the WAS.

The body axis system is obtained from the reference coordinate system by three Euler angle rotations, which are defined with standard aeronautical orientations and notations (references B.8 and B.9).

$$\Gamma_{BAS} = \begin{bmatrix} \cos\theta\cos\psi & \cos\theta\sin\psi & -\sin\theta \\ (\sin\phi\sin\theta\cos\psi - \cos\phi\sin\psi) & (\sin\phi\sin\theta\sin\psi + \cos\phi\cos\psi) & \sin\phi\cos\theta \\ (\cos\phi\sin\theta\cos\psi + \sin\phi\sin\psi) & (\cos\phi\sin\theta\sin\psi - \sin\phi\cos\psi) & \cos\phi\cos\theta \end{bmatrix}$$

(B.4.22d)

The three Euler angle rotations are (in order)

1. A rotation of angle $\psi$ about the $z_0$-axis, into the axes $(x_1,y_1,z_1)$
2. A rotation of angle $\theta$ about the $y_1$-axis, into the axes $(x_2,y_2,z_2)$
3. A rotation of angle $\phi$ about the $x_2$-axis, into the BAS $(x',y',z')$.

The default option for the BAS is $\psi = 180^\circ$, $\theta = 0^\circ$ and $\phi = 180^\circ$ which causes the x'-axis and z'-axis in the BAS to be in the opposite directions of the $x_0$-axis and $z_0$-axis in the RCS, respectively.

The Euler angle rotations are used only for the BAS. However, the rotations defining the SAS and the WAS can be expressed in terms of Euler angles. To help visualize the three Euler angle rotations, and the WAS and SAS orientations, consider figure B.49. This figure illustrates how one set of Euler angles can be used to rotate an axis system from the WAS to the SAS to the RCS, and then a second set can be used to return to the WAS. (The second set corresponds to the PAN AIR transformation of force and moment coefficients, equation (B.4.22a).) In the figure, the delta wing/vertical tail configuration moves with the rotating axes; this wing/tail is shown purely for the purpose of visualizing the axis rotations, and should not be confused with the user input vehicle which is always fixed in the RCS.

In the first Euler angle sequence the rotating axis system is initially coincident with the WAS (which now corresponds to the unprimed coordinate system in equation (B.4.22a)). Then by setting $\psi = \beta$, $\theta = \alpha$, $\phi = 0$, the

rotating axis yaws about the z-axis of the WAS to the SAS, and then pitches about the y-axis of the SAS to the RCS. In the second sequence, starting at the RCS, we return to the WAS by setting $\psi = -\beta_r$, $\theta = -\alpha_r$, and $\phi = \phi_r$, which yaws the rotating axes about the $z_0$-axis (nose right) to the $(x_1,y_1,z_1)$ position, pitches it down about the $y_1$-axis to the $(x_2,y_2,z_2)$ position, and then rolls it about the x-axis of the WAS. (The angles $\psi$ and $\theta$ are negative values.)

The second sequence satisfies the transformations of equations (B.4.22a) and (B.4.22d). The transformations for the SAS and WAS can be expressed in terms of the Euler angles of equation (B.4.22d). The appropriate relations are

$$\psi = -\beta_r \text{ where } \tan \beta_r = \tan \beta / \cos \alpha$$

$$\theta = -\alpha_r \text{ where } \tan \alpha_r = \cos \beta_r \tan \alpha$$

$$\phi = \phi_r \text{ where } \cos \phi_r = \cos \alpha / \cos \alpha_r$$

For each coordinate system, PAN AIR allows the moment reference point R to be at an arbitrary position, its location being given by coordinates in the RCS. (See record FM3, and equation (0.4.11) of the Theory Document.) The components of the force coefficient are transformed by equation (B.4.22a), with the appropriate $\Gamma$ matrix.

$$\{\vec{C_F}\} = \begin{Bmatrix} FX \\ FY \\ FZ \end{Bmatrix} = \frac{1}{SR} \quad [\Gamma] \{\vec{I_F}\} \tag{B.4.23a}$$

The components of the moment coefficient are transformed by the relation

$$\{\vec{C_M}\} = \begin{Bmatrix} MX \\ MY \\ MZ \end{Bmatrix} = \frac{1}{SR} \begin{bmatrix} \frac{1}{BR} & 0 & 0 \\ 0 & \frac{1}{CR} & 0 \\ 0 & 0 & \frac{1}{BR} \end{bmatrix} [\Gamma] \{\vec{I_M} - \{\vec{R_0} \times \vec{I_F}\}\} \tag{B.4.23b}$$

The "forces" and "moments" in equations (B.4.22) are based on integrals of the pressure coefficient, that is, they involve $(p-p_\infty)$ rather than p alone, see equation (B.4.11). Thus the coefficients calculated by PAN AIR are true force and moment coefficients only for cases in which the net effect of $p_\infty$ integrates to zero. This will occur when the individual network force and moment coefficients are summed over all networks making up the vehicle boundary (since the net force due to the constant pressure $p_\infty$ acting on a closed surface is zero). The correlation of the force and moment coefficients in equations (B.4.22) with (1) the coefficients often used in wind tunnel test reports, see figure B.50 (taken from reference B.10), and (2) the coefficients in reference B.9 is given in table B.3.

| PAN AIR Coefficients CDP Output | Wind Tunnel Coefficients of figure B.50 | | | Coefficients of reference B.9, Table 5 | | |
|---|---|---|---|---|---|---|
| | Body Axes[2] | Stability Axes | Wind Axes | Body Axes[2] | Wind Tunnel Stability Axes | Wind Axes |
| FX = | $C_A$ | $C_D$ | $C_{D,w}$ | $C_X$ or $-C_A$ | $C_D'$ | $C_D$ |
| FY = | $C_Y$ | $C_Y$ | $C_C$ | $C_Y$ | $C_Y$ | $C_C$ |
| FZ = | $C_N$ | $C_L$ | $C_L$ | $C_Z$ or $-C_N$ | $C_L$ | $C_L$ |
| MX (roll) = | $-C_l$ | $-C_{l,s}$ | $-C_{l,w}$ | $C_l$ | $-C_{l,wt}$ | $-C_{l,w}$ |
| MY (pitch) = | $C_m$ | $C_m$ | $C_{m,w}$ | $C_m$ | $C_{m,wt}$ | $C_{m,w}$ |
| MZ (yaw) = | $-C_n$ | $-C_{n,s}$ | $-C_{n,w}$ | $C_n$ | $-C_{n,wt}$ | $-C_{n,w}$ |
| PAN AIR AXIS SYSTEM[4] | RCS | SAS | WAS | BAS[3] | SAS | WAS |

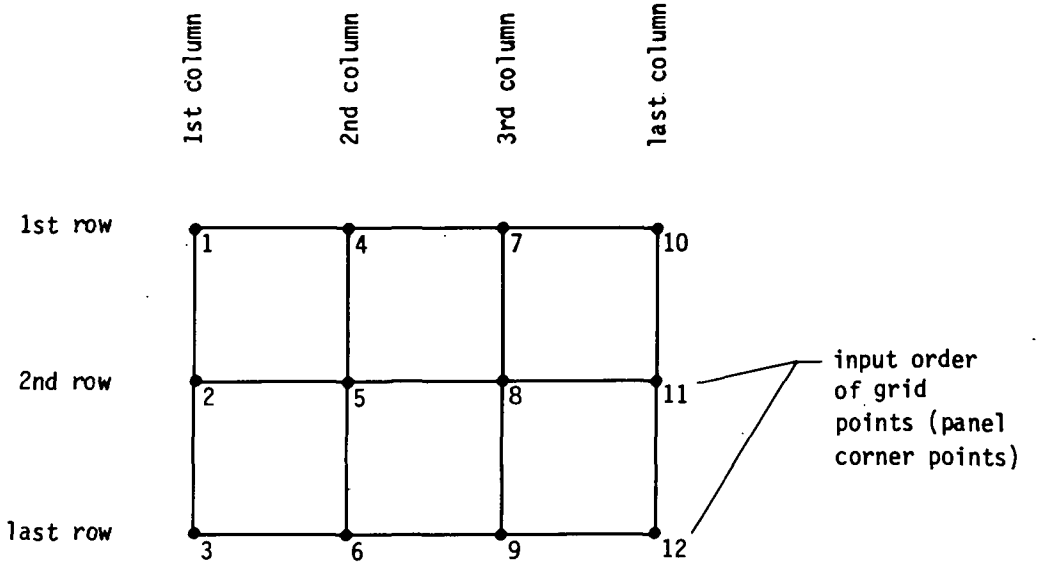
1 Moments in PAN AIR and reference B.9 (NASA SP-3070) are all right hand rule. In figure B.50, moments about the x and z axes are left hand rule.

2 The body axes of figure B.50 are analogous to the PAN AIR RCS, that is, positive x, y, and z axes out the tail, out the right wing, and up (through the canopy), respectively. The positive x and z axes of reference B.9 are in the reverse directions from those shown in figure B.50.

3 This is for the default values $\psi = 180^\circ$, $\theta = 0^\circ$, $\phi = 180^\circ$, which give the PAN AIR BAS axes the same orientation as the reference B.9 body axes.

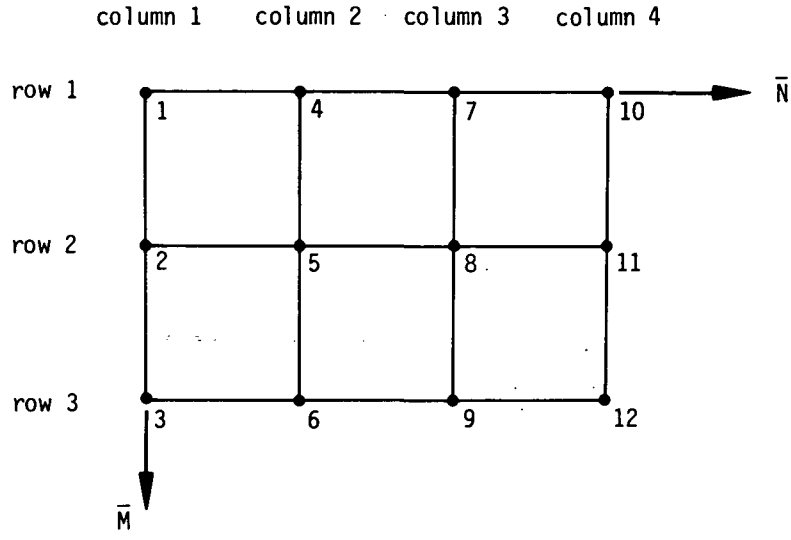
4 See figure B.49 and record FM3.

Table B.3 Correlation of PAN AIR force and moment coefficients with those of figure B.50 and reference B.9 (see footnote 1)

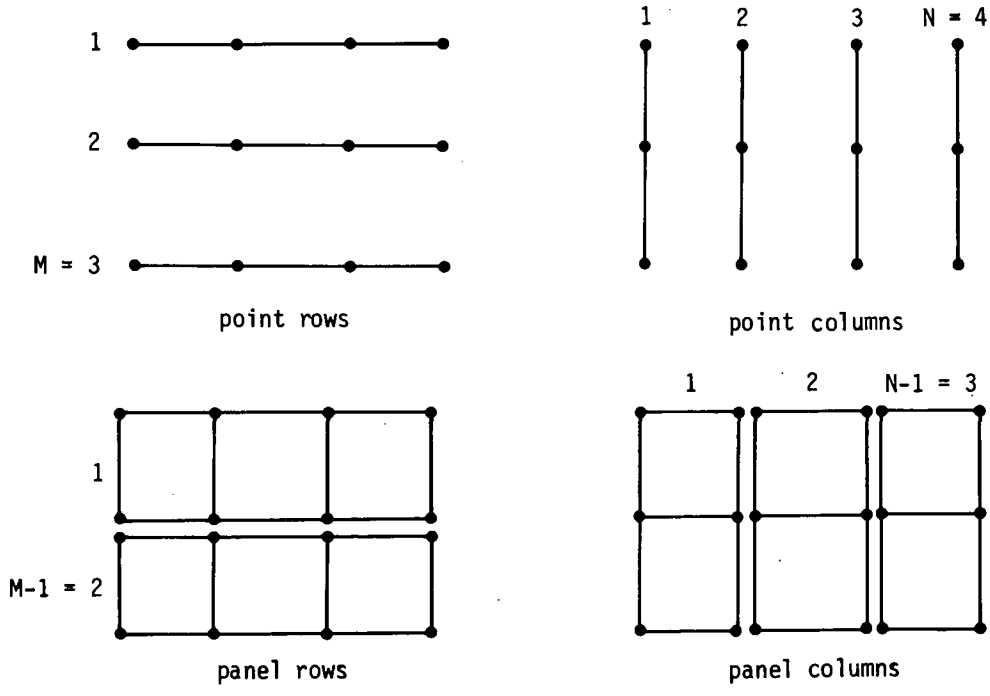



(a) grid point input scheme; points are input by column

Figure B.1 - Example of network grid point input order and related nomenclature




(b) the grid point input order defines the $\bar{M}$ and $\bar{N}$ directions




(c) rows and columns of points and panels

Figure B.1 - Concluded

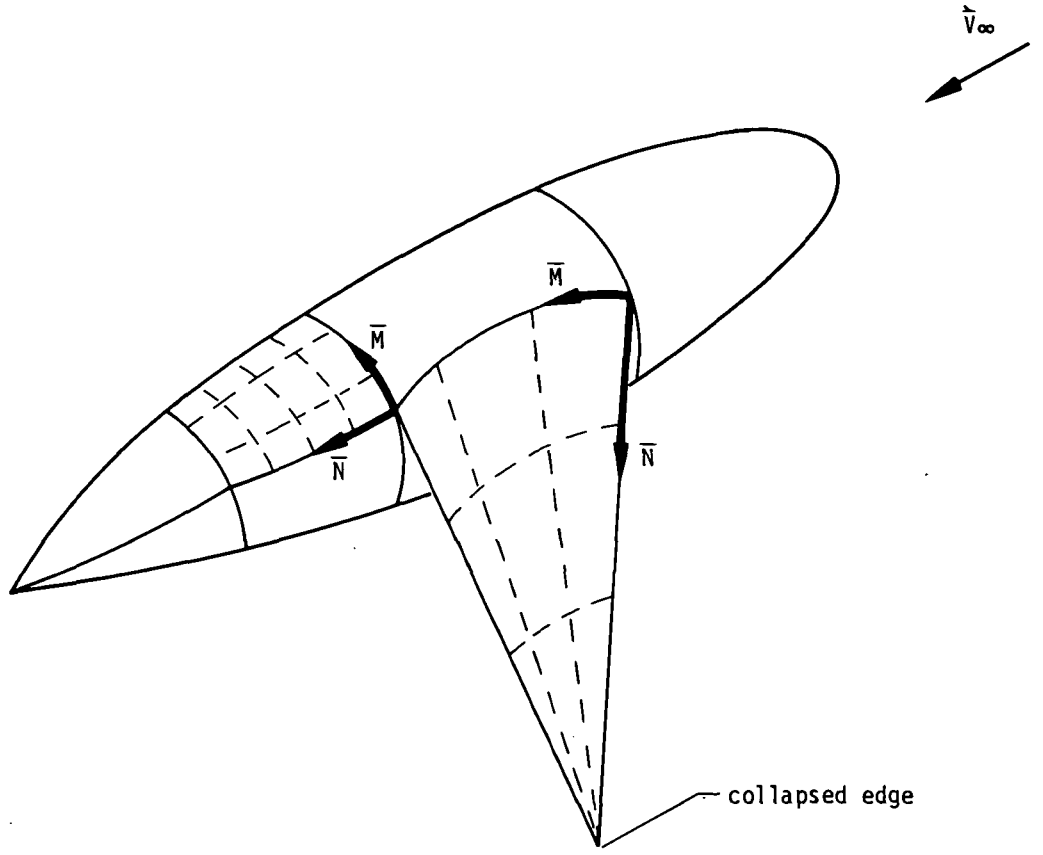



Figure B.2 - Example of arbitrary choices for $\overline{M}$ and $\overline{N}$ directions

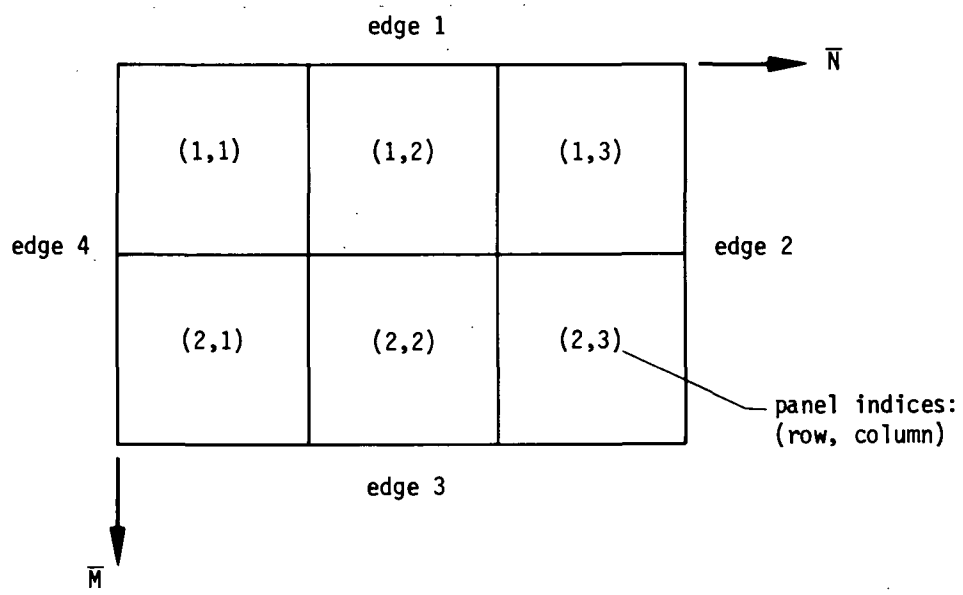



Figure B.3 - Conventions for network edge numbering and panel indexing

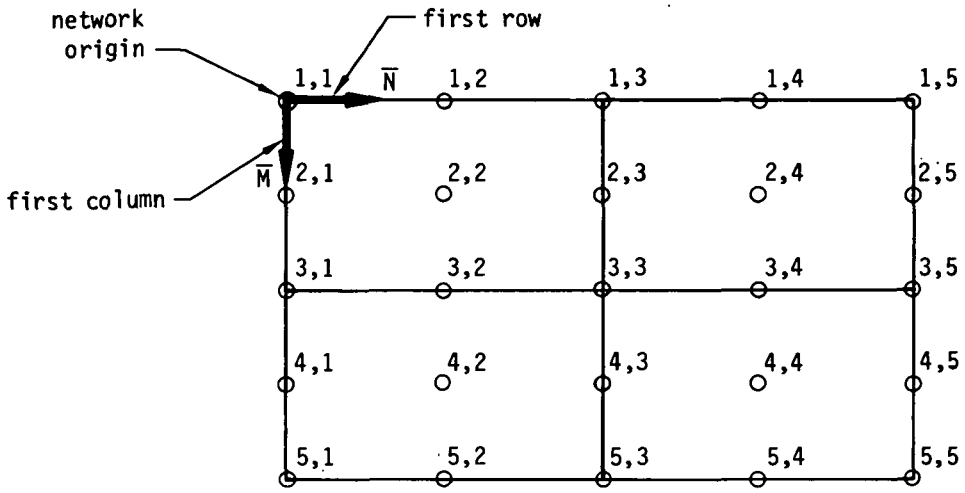



Figure B.4 - Example of indexing convention for enriched panel corner point array

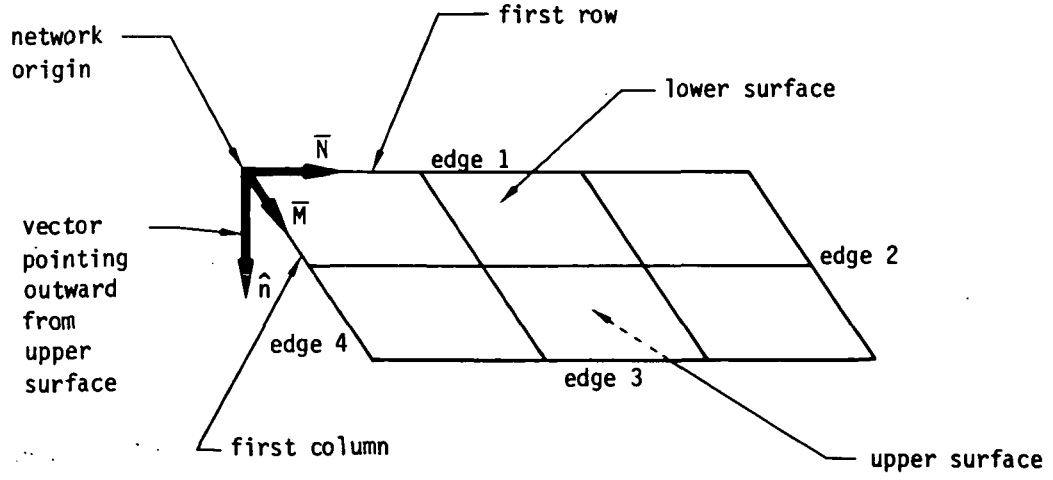
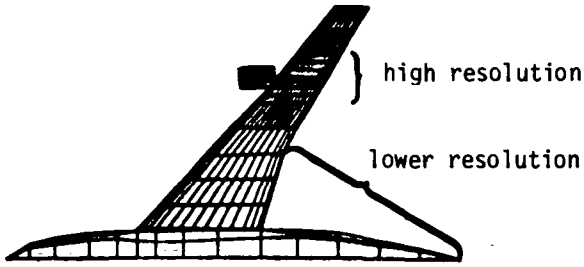
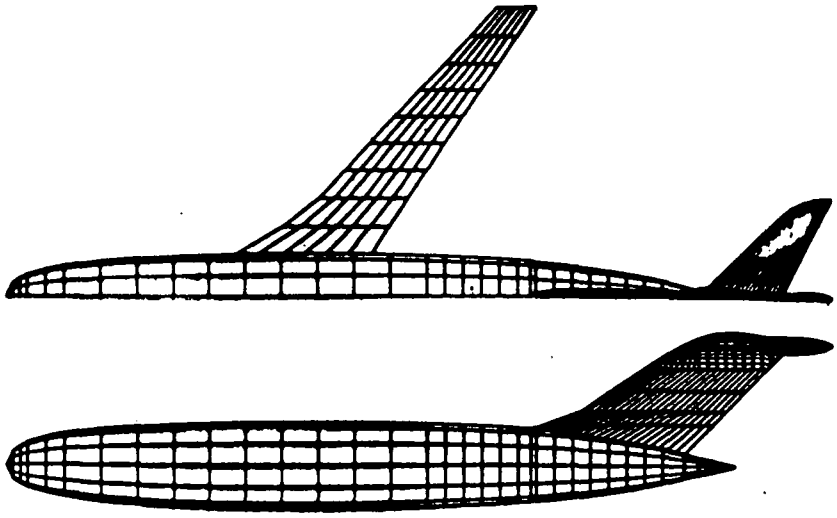



Figure B.5 - Definition of network upper and lower surfaces

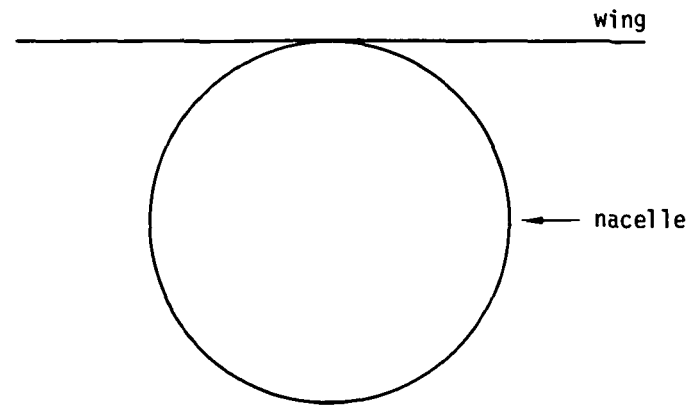



(a) nacelle-wing interference study

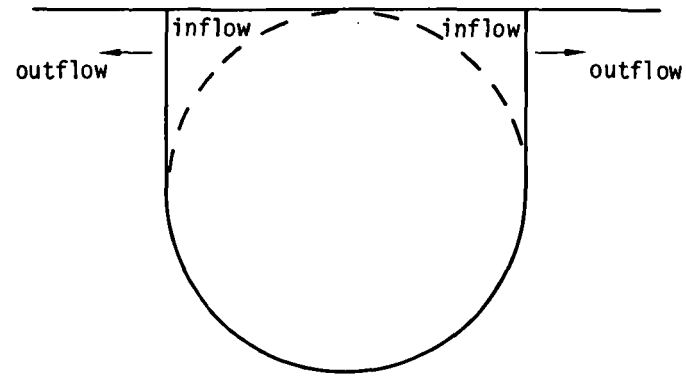


(b) empennage study

Figure B.6 - Examples of variable paneling density




(a) original model




(b) revised model

Figure B.7 - Example of nacelle installation with possible numerical problems in supersonic flow

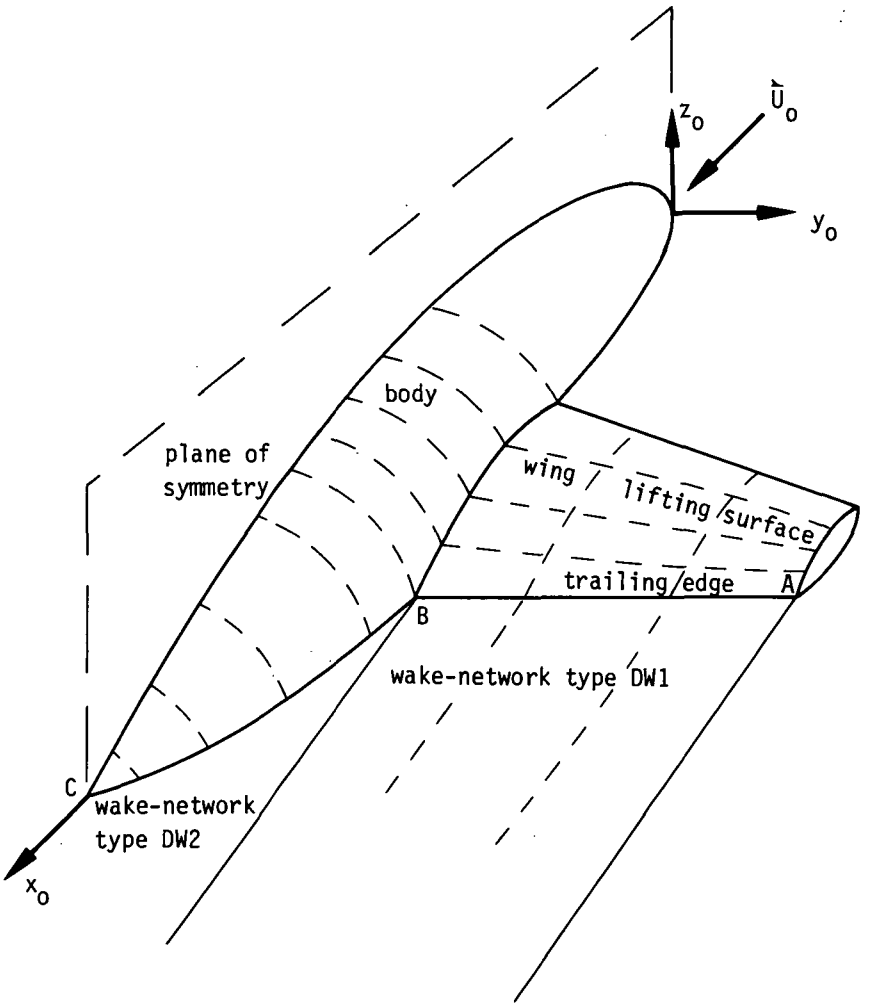



Figure B.8 - Example of use of wake networks

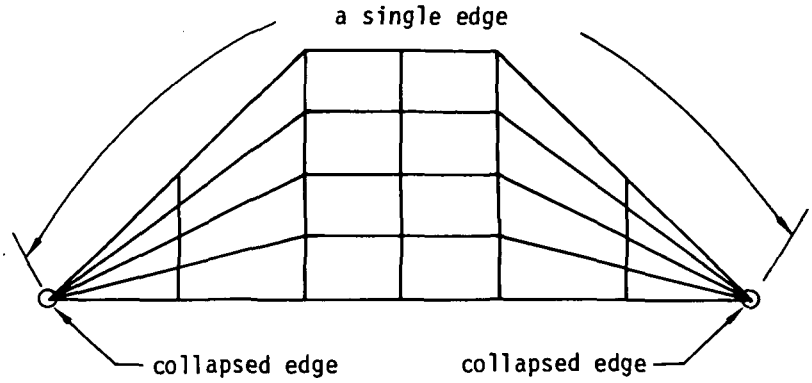



Figure B.9 - Example of network with two collapsed edges

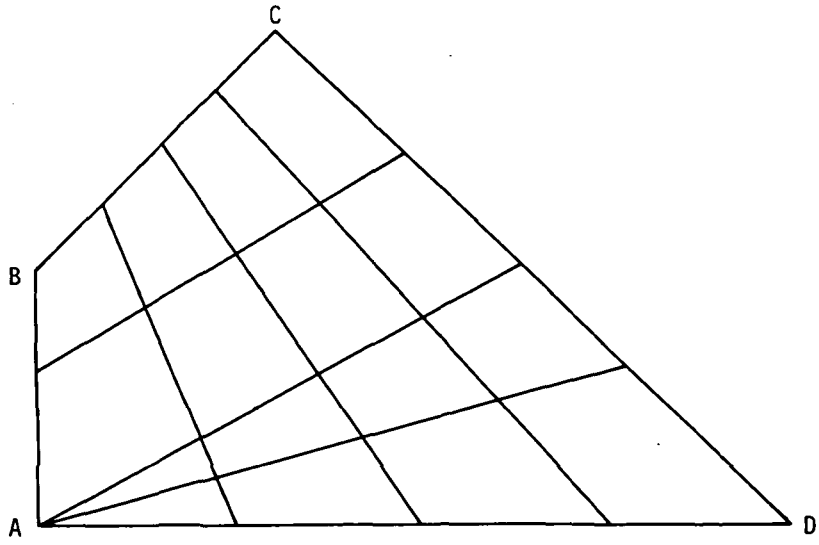



Figure B.10 - Example of prohibited network

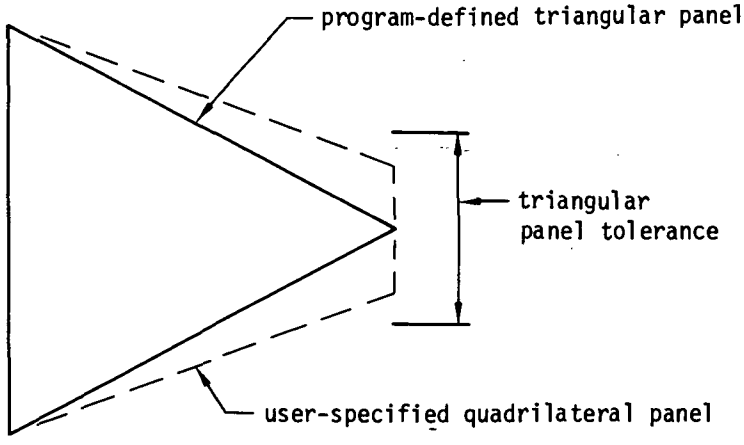



Figure B.11 - Example of triangular panel definition capability

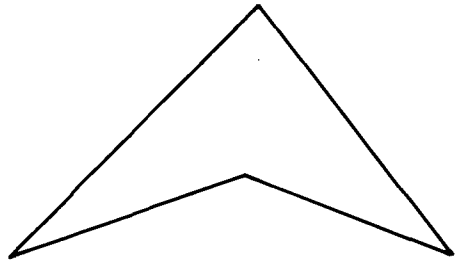


Figure B.12 - Example of non-convex panel

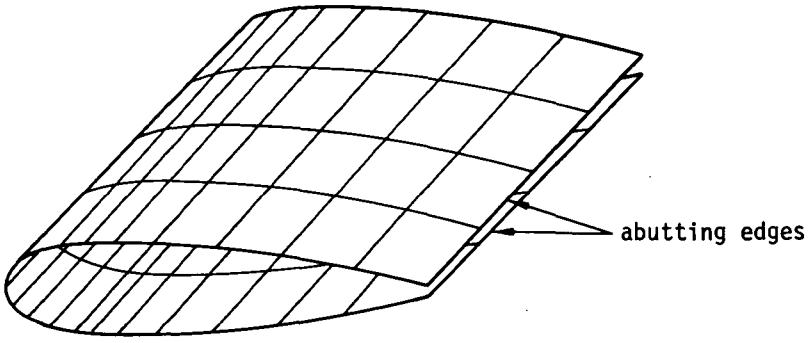
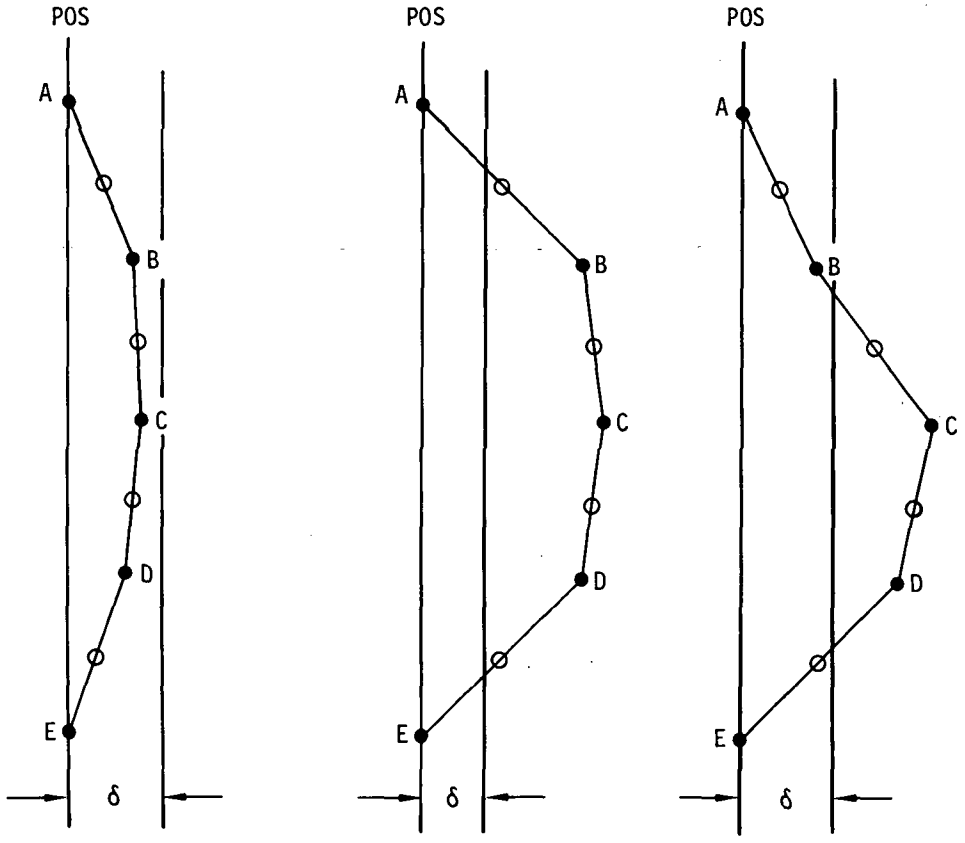



Figure B.13 - Example of a network with abutting edges




(a) special treatment of reflection. (b) regular reflection (c) error condition

δ = tolerance distance (record G7)
POS = plane of symmetry
A, B, C, D, E = panel grid points
O = panel center points

Figure B.14 - Edge views showing examples of networks and plane of symmetry reflection options

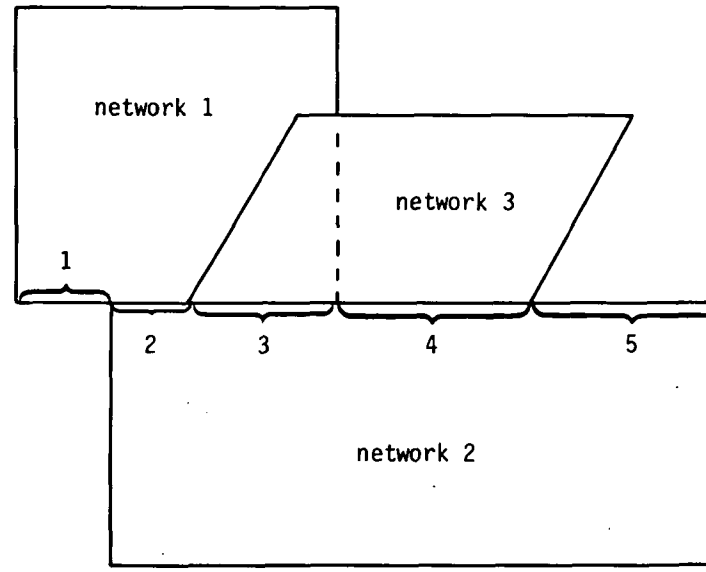
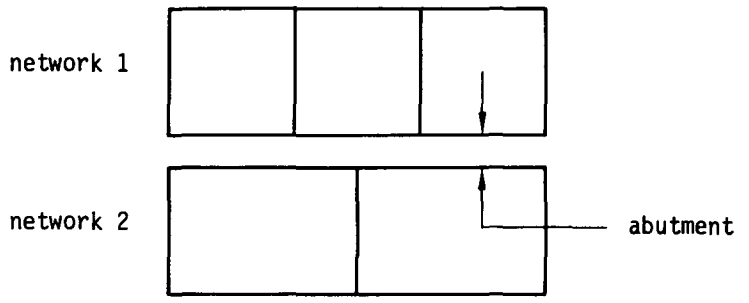
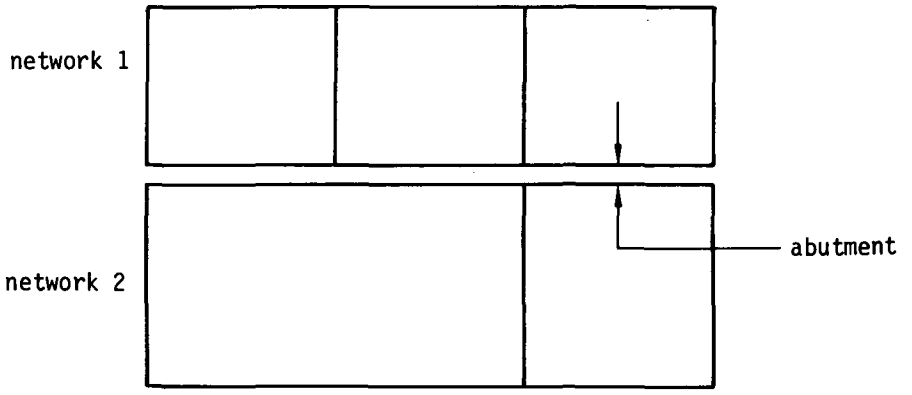



Figure B.15 - Example of a general network abutment




(a) poor practice : panel corner points not matching




(b) good practice : panel corner points matching as much as possible

Figure B.16 - Examples of poor and good modeling practice in matching corner points at an abutment

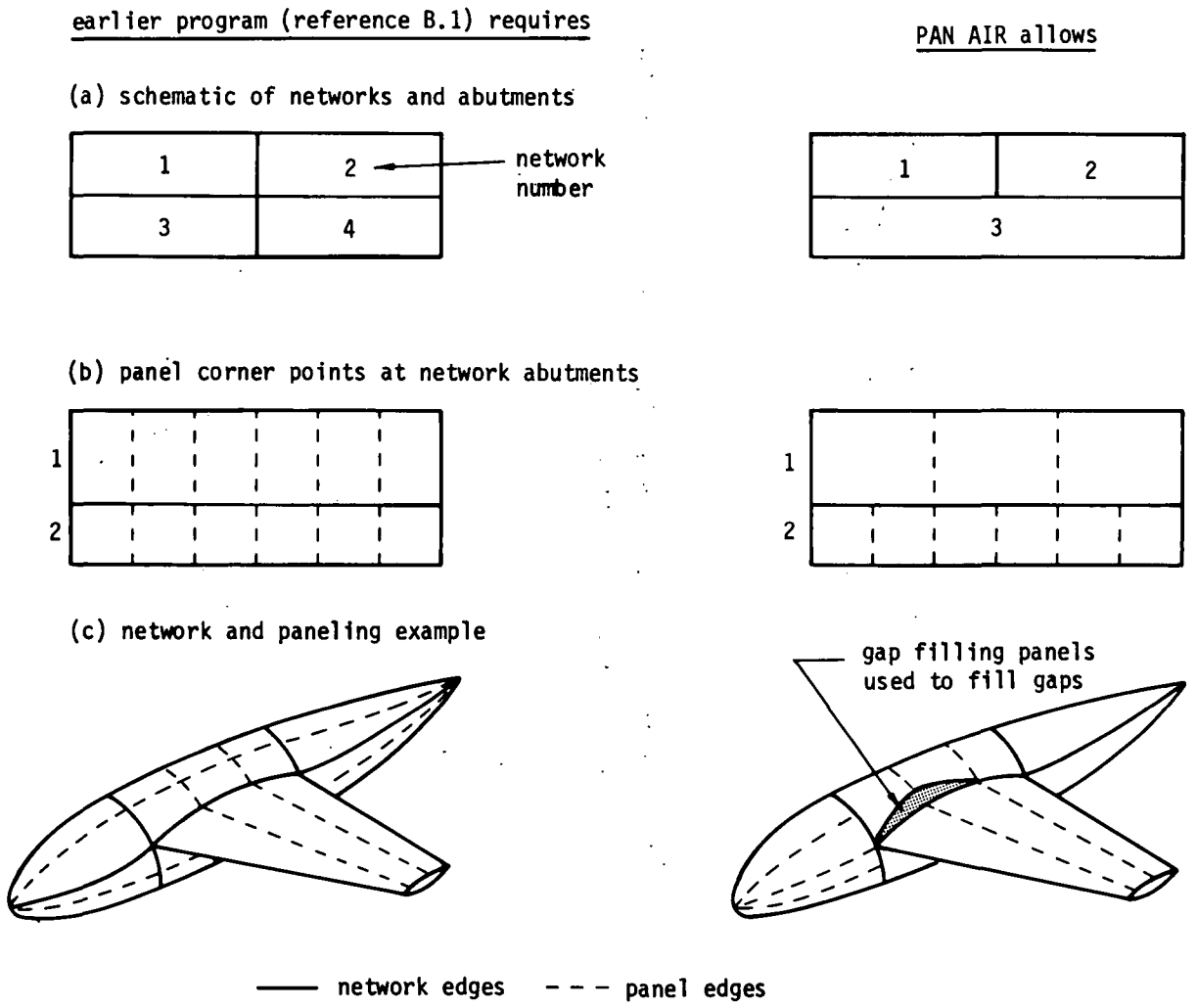



Figure B.17 - Examples of what PAN AIR allows at network abutments

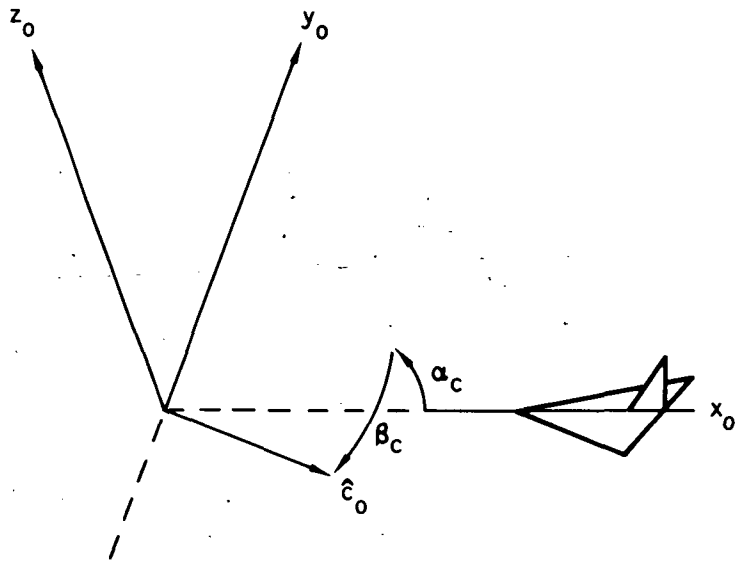



Figure B.18 - Definition of the compressibility vector $\hat{c}_o$ in terms of $\alpha_c$ and $\beta_c$ and the reference coordinate system $(x_o, y_o, z_o)$

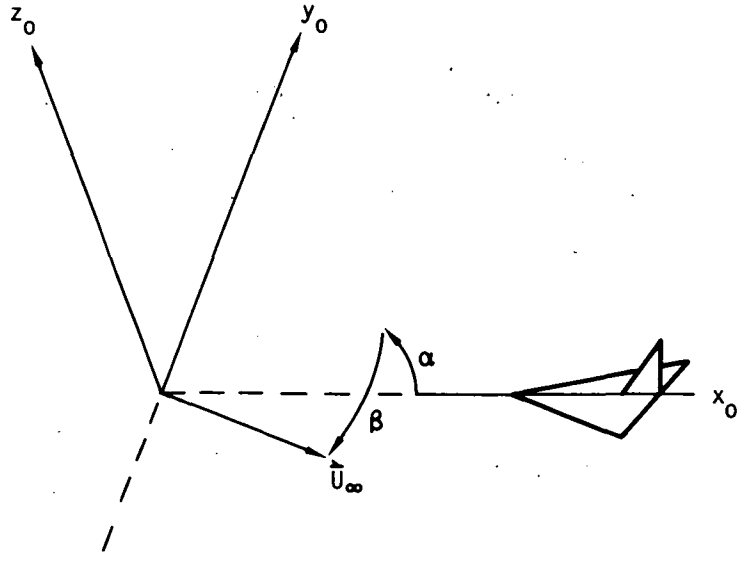
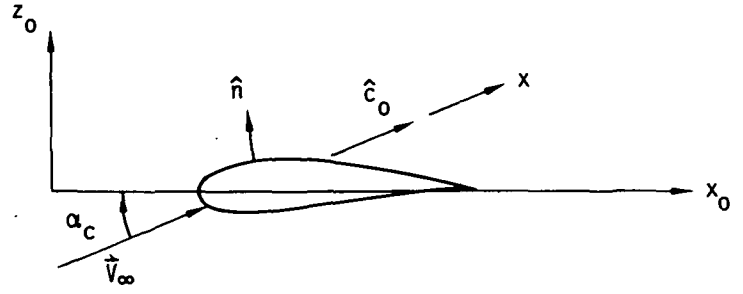
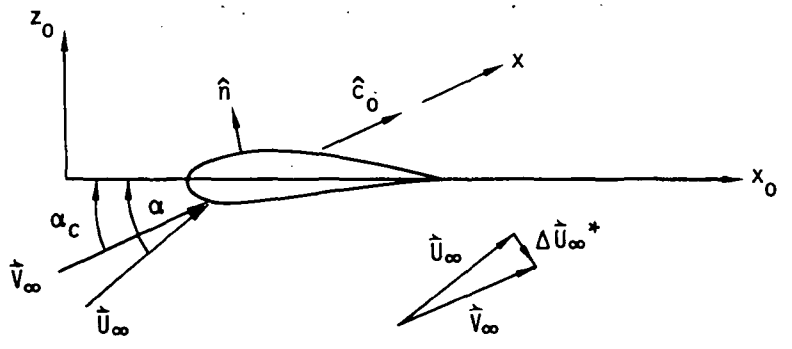



Figure B.19 - Definition of the uniform onset flow in terms of $\alpha$ and $\beta$ and the reference coordinate system $(x_o, y_o, z_o)$




boundary condition: $(\vec{V}_\infty + \vec{w}) \cdot \hat{n} = 0$

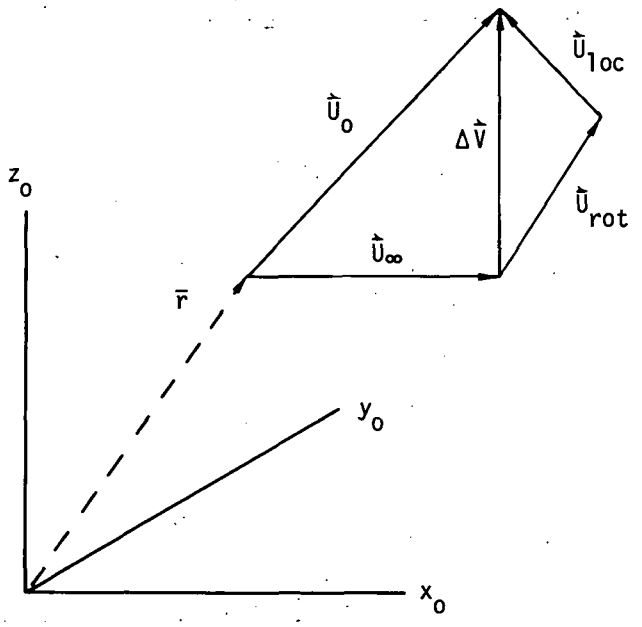
(a) exact model requiring a separate AIC matrix for each angle of attack, $\alpha = \alpha_c$




boundary condition: $(\vec{U}_\infty + \vec{w}) \cdot \hat{n} = 0$

(b) approximate model requiring only a single AIC matix for multiple angles of attack, $\alpha \neq \alpha_c$

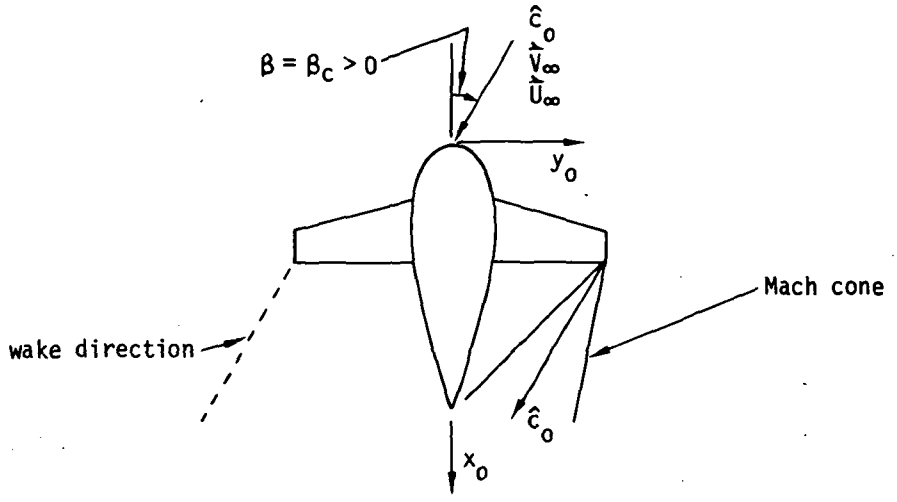
Figure B.20 - Exact and approximate models for multiple angles of attack at fixed Mach number



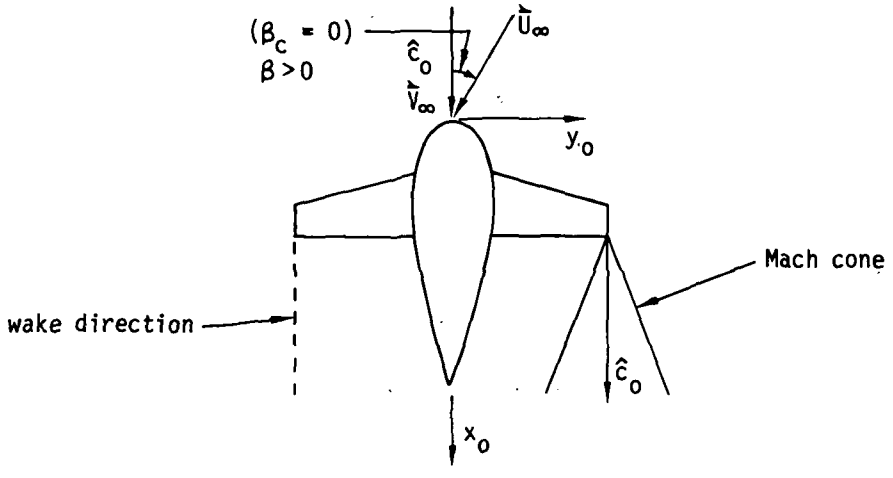

$$\vec{U}_o = \vec{U}_\infty + \Delta\vec{V}$$

$$\Delta\vec{V} = \vec{U}_{rot} + \vec{U}_{loc}$$

Figure B.21 - Composition of total onset flow vector

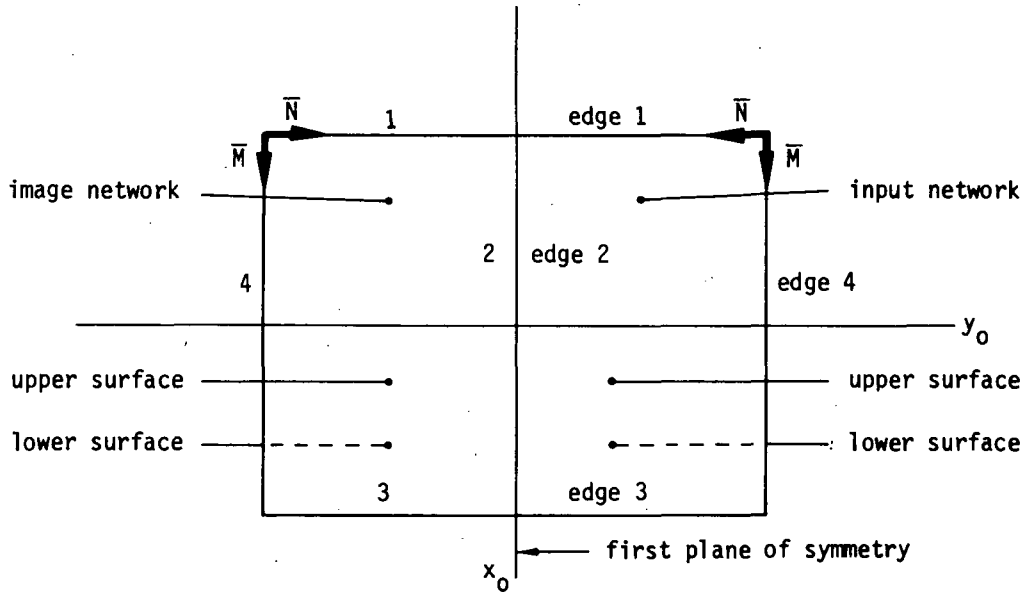



(a) exact model without configuration symmetry

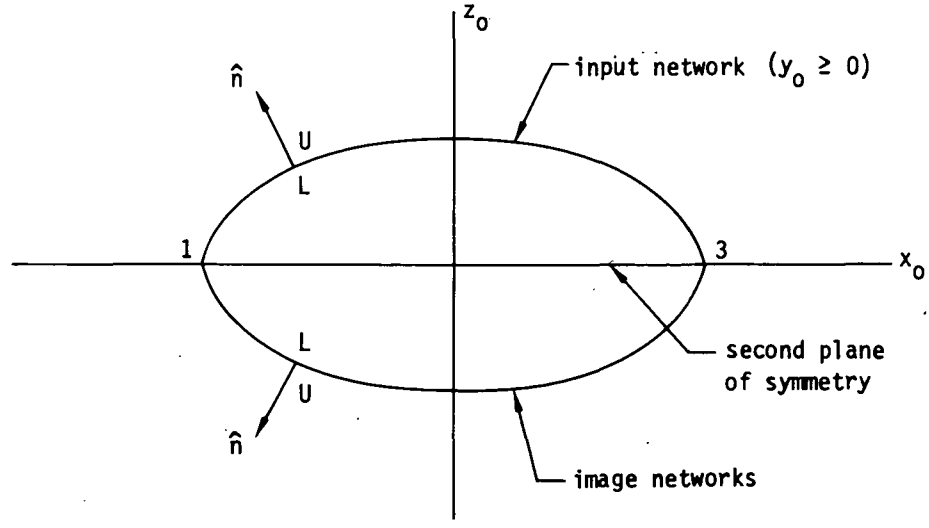



(b) approximate model with configuration symmetry

Figure B.22 - Examples of asymmetric flow, without and with configuration symmetry




(a) top view




(b) side view

Figure B.23 - Example of network reflection in two planes of symmetry

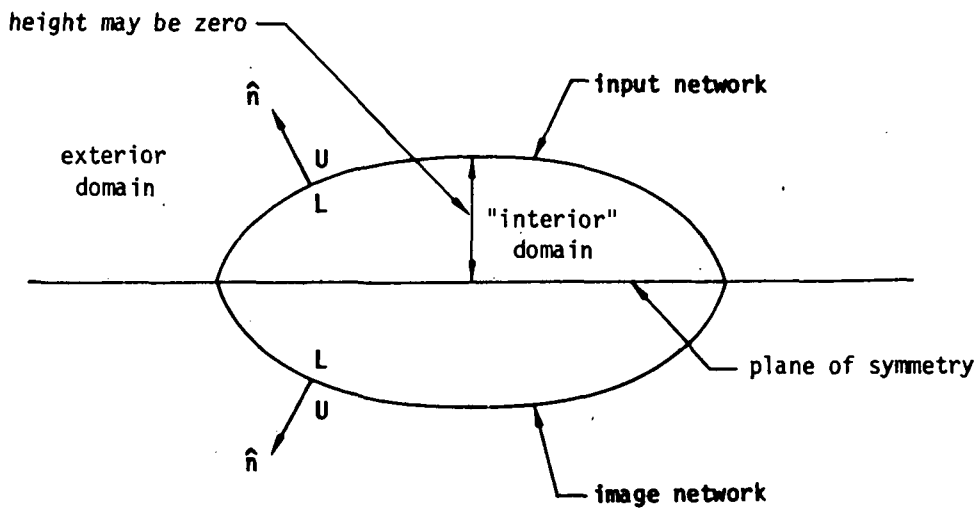



Figure B.24 - Schematic form for analysis of network in a plane of symmetry

| boundary condition type | left-hand side | | right-hand side |
|---|---|---|---|
| mass flux analysis | $a_U(\vec{w}_U \cdot \hat{n}) + a_L(\vec{w}_L \cdot \hat{n})$<br>$a_A(\vec{w}_A \cdot \hat{n}) + a_D\sigma$ | | $b_n\vec{U}_o \cdot \hat{n}$ |
| potential | $c_U\phi_U + c_L\phi_L$<br>$c_A\phi_A + c_D\mu$ | | $b_p\vec{U}_\infty \cdot \vec{\psi}$ |
| velocity design | $\vec{t}_U \cdot \vec{v}_U + \vec{t}_L \cdot \vec{v}_L$<br>$\vec{t}_A \cdot \vec{v}_A + \vec{t}_D \cdot \vec{v}\mu$ | = | $b_t\vec{t}_t \cdot \vec{U}_o$ |
| velocity analysis | $e_U(\vec{v}_U \cdot \hat{n}) + e_L(\vec{v}_L \cdot \hat{n})$<br>$e_A(\vec{v}_A \cdot \hat{n}) + e_D(\vec{v}_D \cdot \hat{n})$ | | $\beta$ |

where

$\vec{w}$ = perturbation mass flux
$\hat{n}$ = panel normal
$\vec{t}$ = panel tangent
$\vec{v}$ = perturbation velocity
$\phi$ = perturbation velocity potential
$\sigma$ = source strength
$\mu$ = doublet strength
$\beta$ = total specified flow
$\vec{\psi} = (x/s\beta^2, y, z)$
$\vec{U}_o$ = total onset flow
$\vec{U}_\infty$ = uniform onset flow

subscripts:

U = upper
L = lower
A = average
D = difference
n = normal to panel
p = potential
t = tangent to panel

Figure B.25 - General boundary condition equation

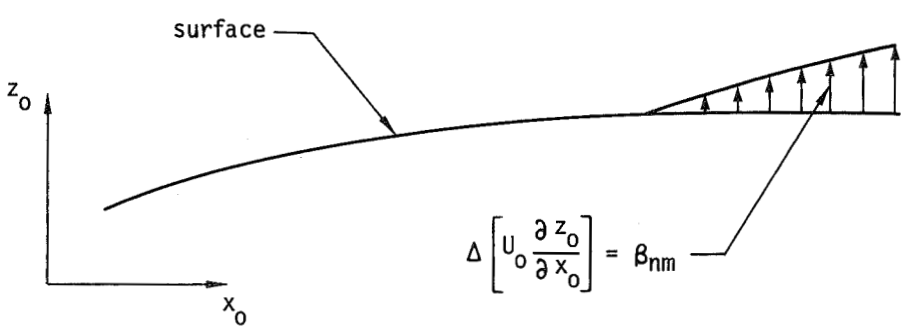
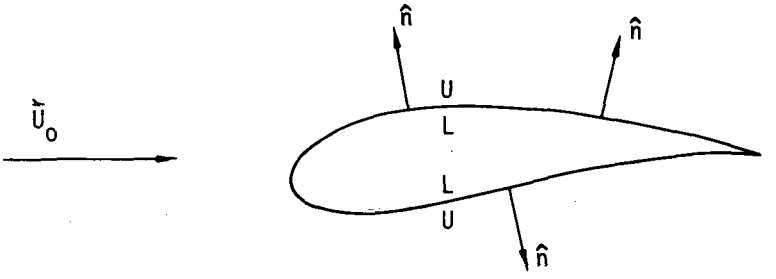
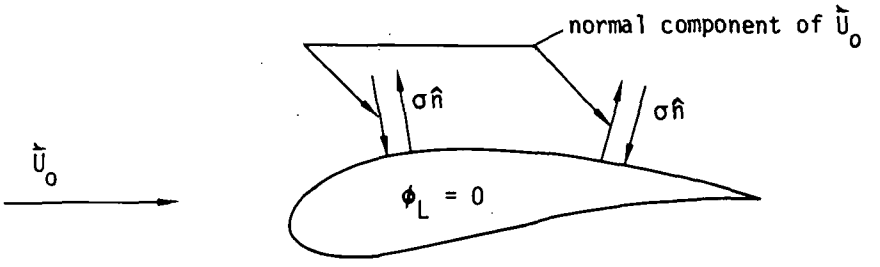


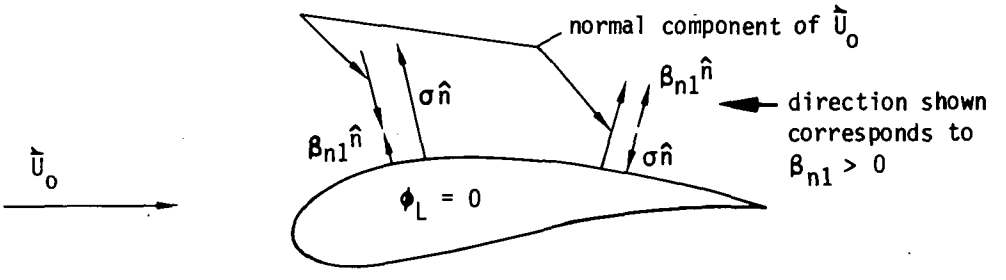

Figure B.26 - Specified flow on a linearized surface representation




(a) upper side of network(s) wetted by the physical flow

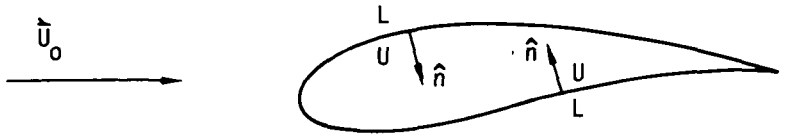



(b) $\sigma = \tilde{w}_U \cdot \hat{n} = -\tilde{U}_o \cdot \hat{n}$ for impermeable surface

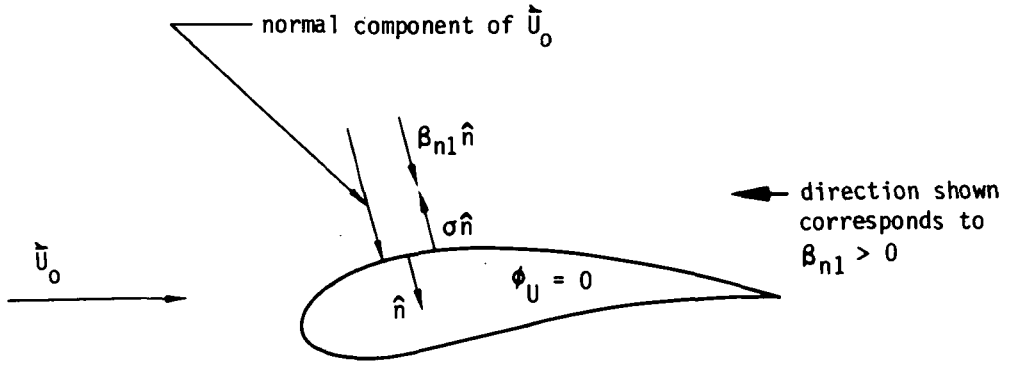



(c) $\sigma = \tilde{w}_U \cdot \hat{n} = -\tilde{U}_o \cdot \hat{n} + \beta_{n1}$ gives net normal mass flux of amount $\tilde{w}_U \cdot \hat{n} = \beta_{n1}$

Figure B.27 - Specified normal mass flux on upper surface of thick configuration: class 2, subclass 1 boundary condition




(a) lower side of network(s) wetted by the physical flow




(b) $-\sigma = \tilde{w}_L \cdot \hat{n} = -\tilde{U}_o \cdot \hat{n} + \beta_{n1}$ gives net normal mass flux of amount $\tilde{w}_L \cdot \hat{n} = \beta_{n1}$

Figure B.28 - Specified normal mass flux on lower surface of thick configuration: class 2, subclass 2 boundary condition

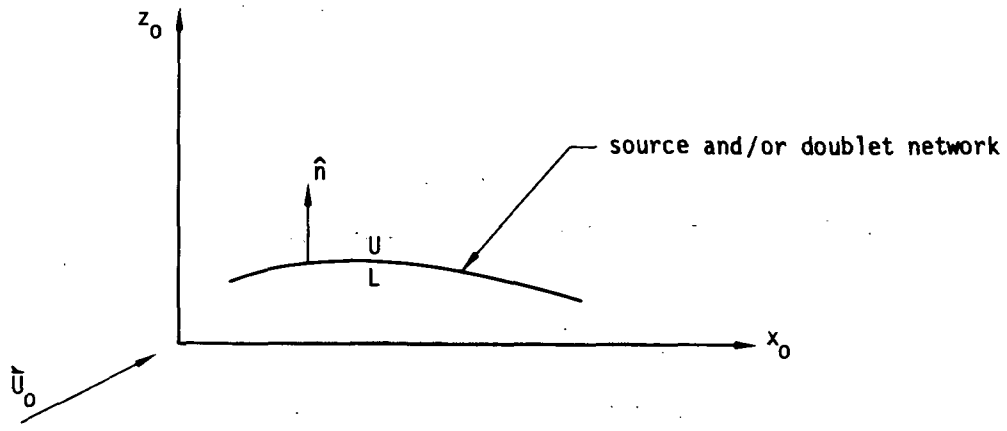



Figure B.29 - A thin ("average") configuration model

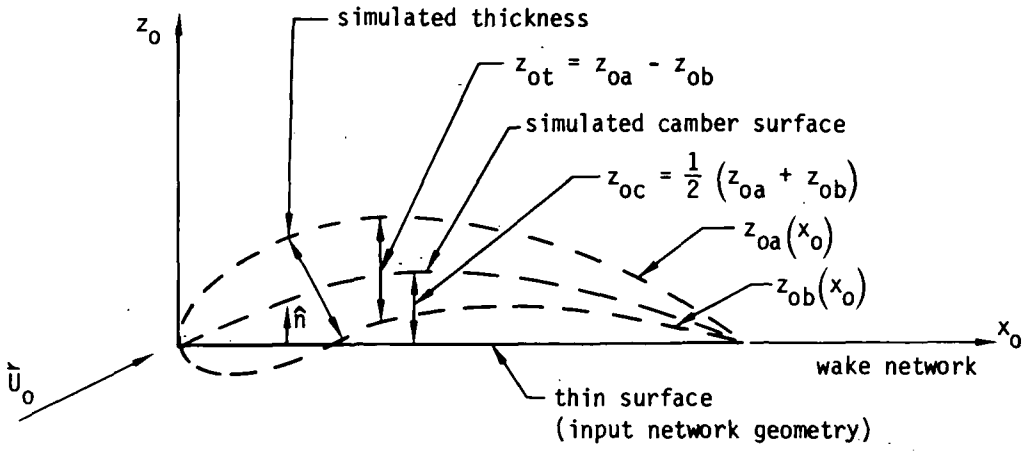



Figure B.30 - Use of specified normal mass flux on a thin configuration surface to simulate camber and thickness: class 2, subclass 5 boundary condition

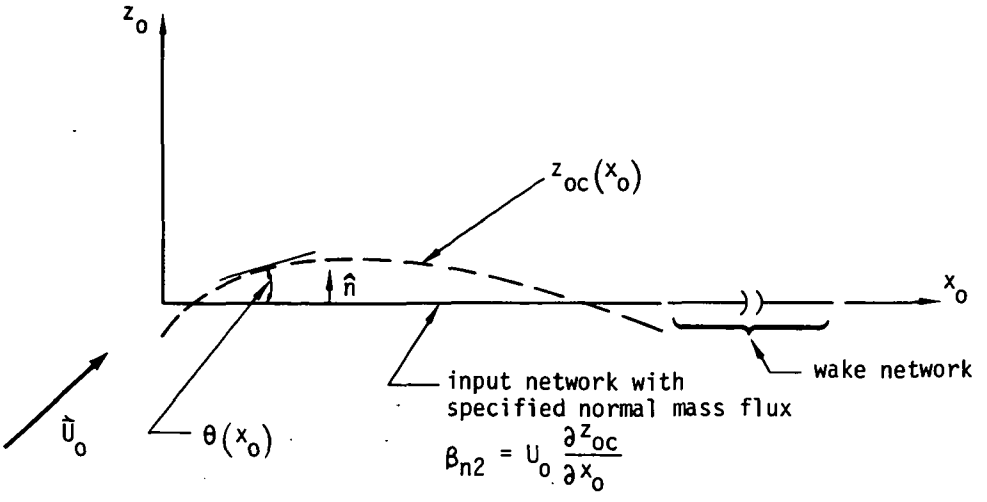



Figure B.31 - Use of flat doublet network to simulate a thin cambered lifting surface: class 2, subclass 3 boundary condition

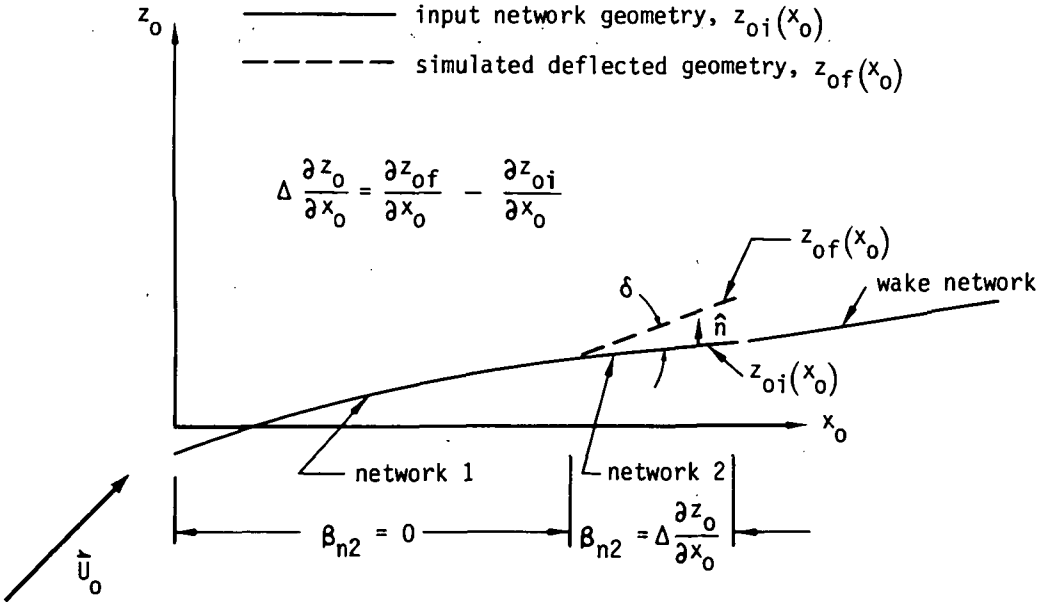



Figure B.32 - Use of specified mass flux $\beta_{n2}$, normal to the input geometry $z_{oi}(x_o)$, to simulate a deflected flap surface $z_{of}(x_o)$: class 2, subclass 3 boundary condition

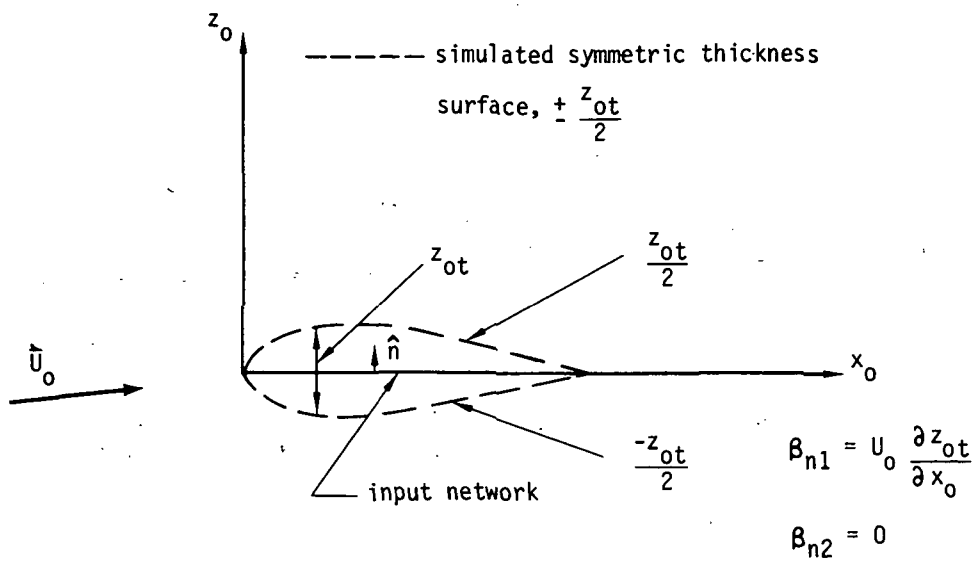



Figure B.33 - Use of specified mass flux to simulate symmetric thickness

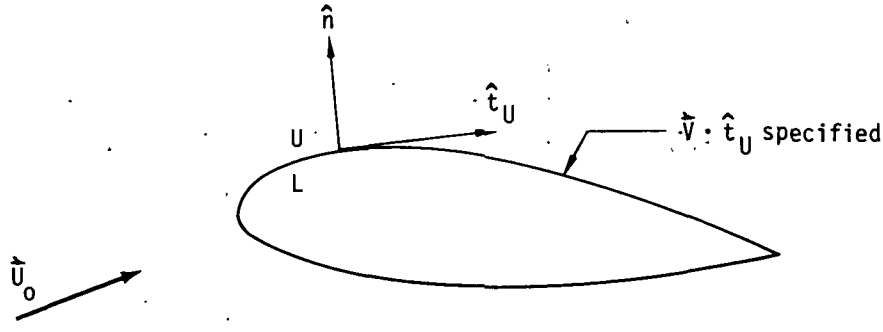



Figure B.34 - Specified tangential velocity on upper surface of thick configuration: class 3, subclass 1 boundary condition

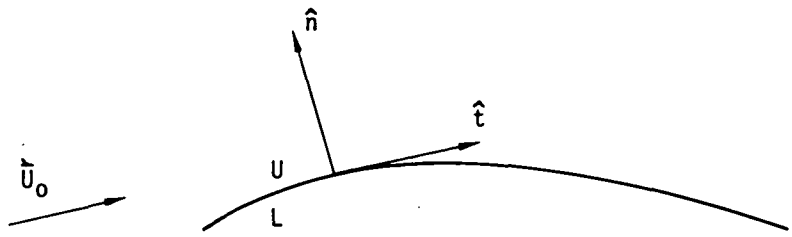



Figure B.35 - Impermeable thin configuration for design problems: class 3, subclass 3 to 6 boundary conditions

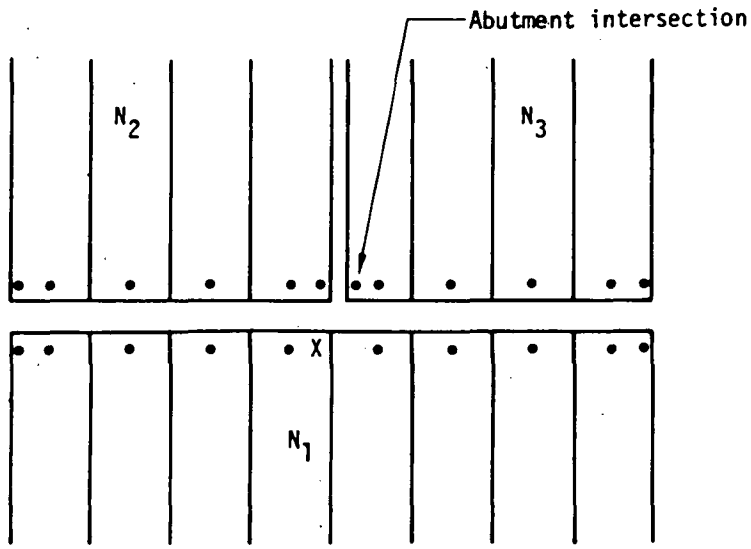
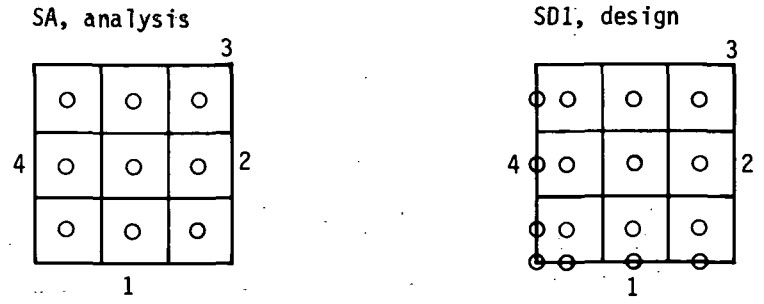
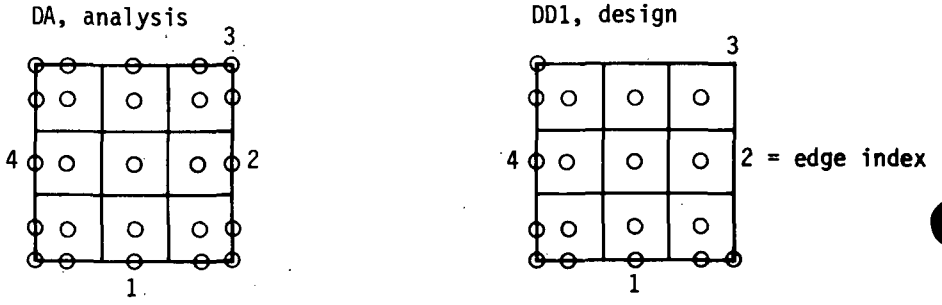



Figure B.36 - Example of an additional control point introduced at a network abutment

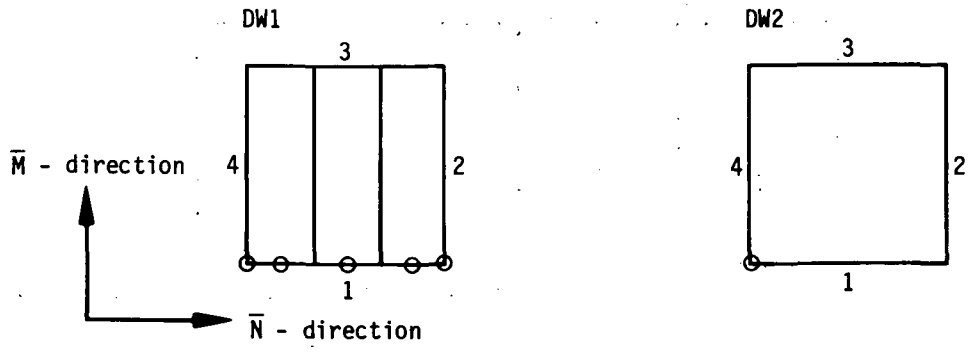
source singularity types




doublet singularity types




wake singularity types (doublet singularities only)




O boundary condition location point

Figure B.37 - Standard boundary condition location point arrays on sample networks

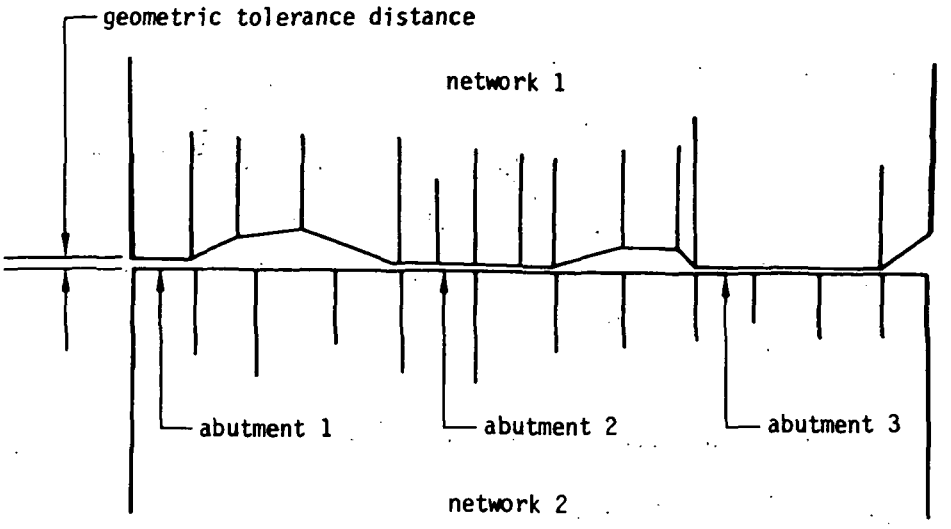



Figure B.38 - Example of multiple abutments between two network edges

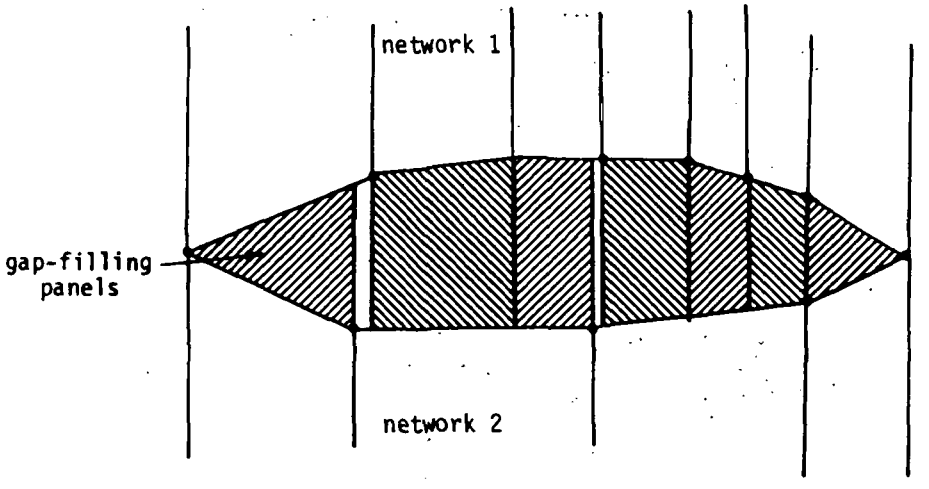



Figure B.39 - Example of creation of gap-filling panels in a network abutment

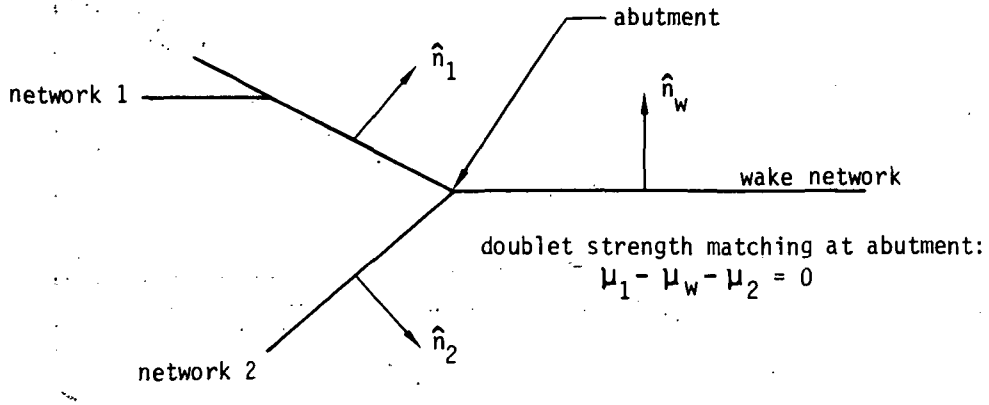
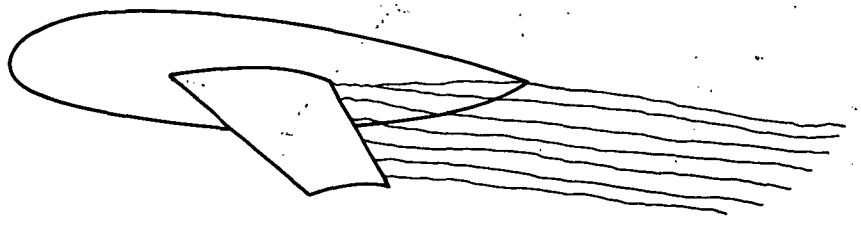
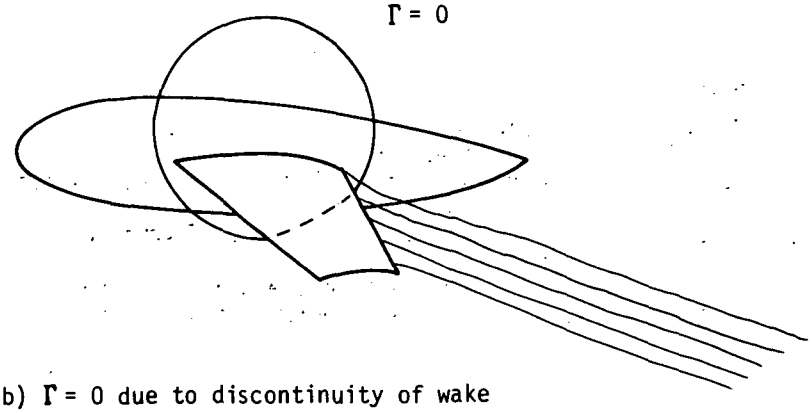



Figure B.40 - Example of doublet strength matching at abutment of three networks

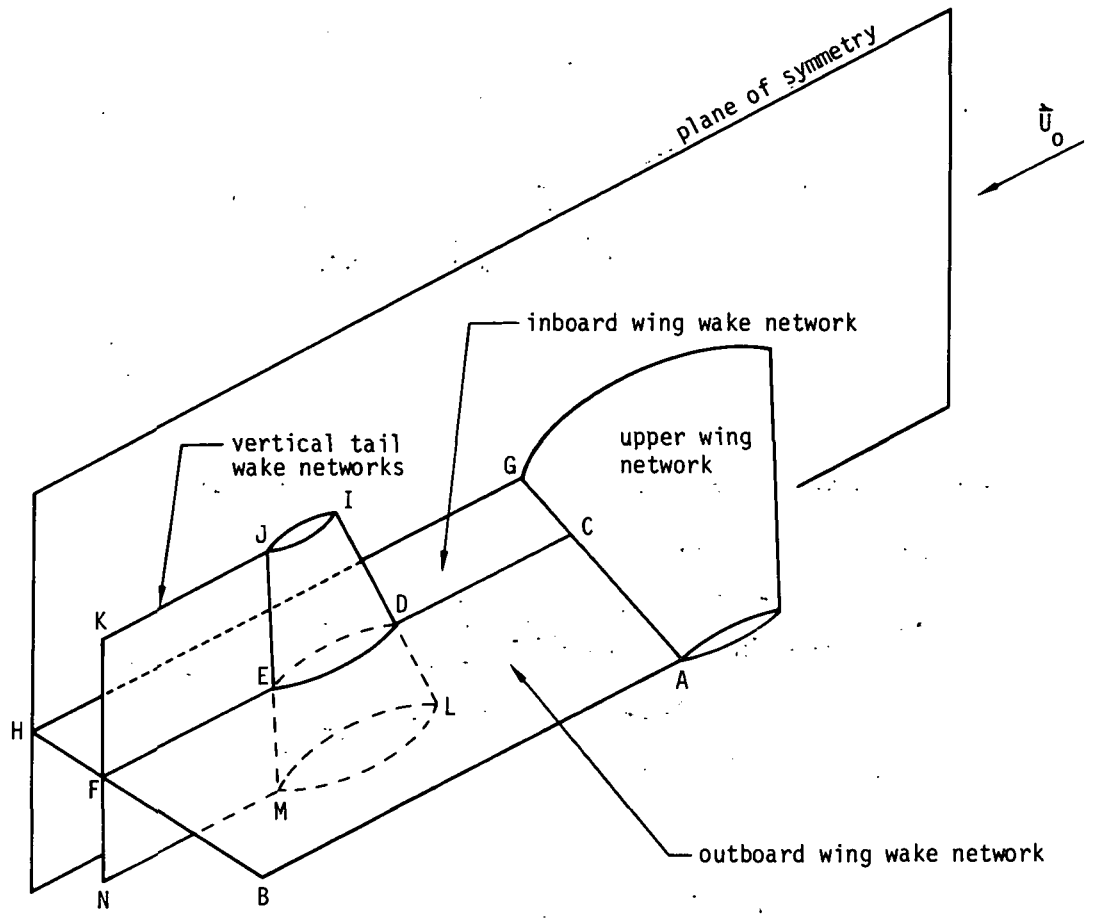


(a) physical location of wake




(b) $\Gamma = 0$ due to discontinuity of wake

Figure B.41 - Example of wake surface discontinuity behind inboard part of wing

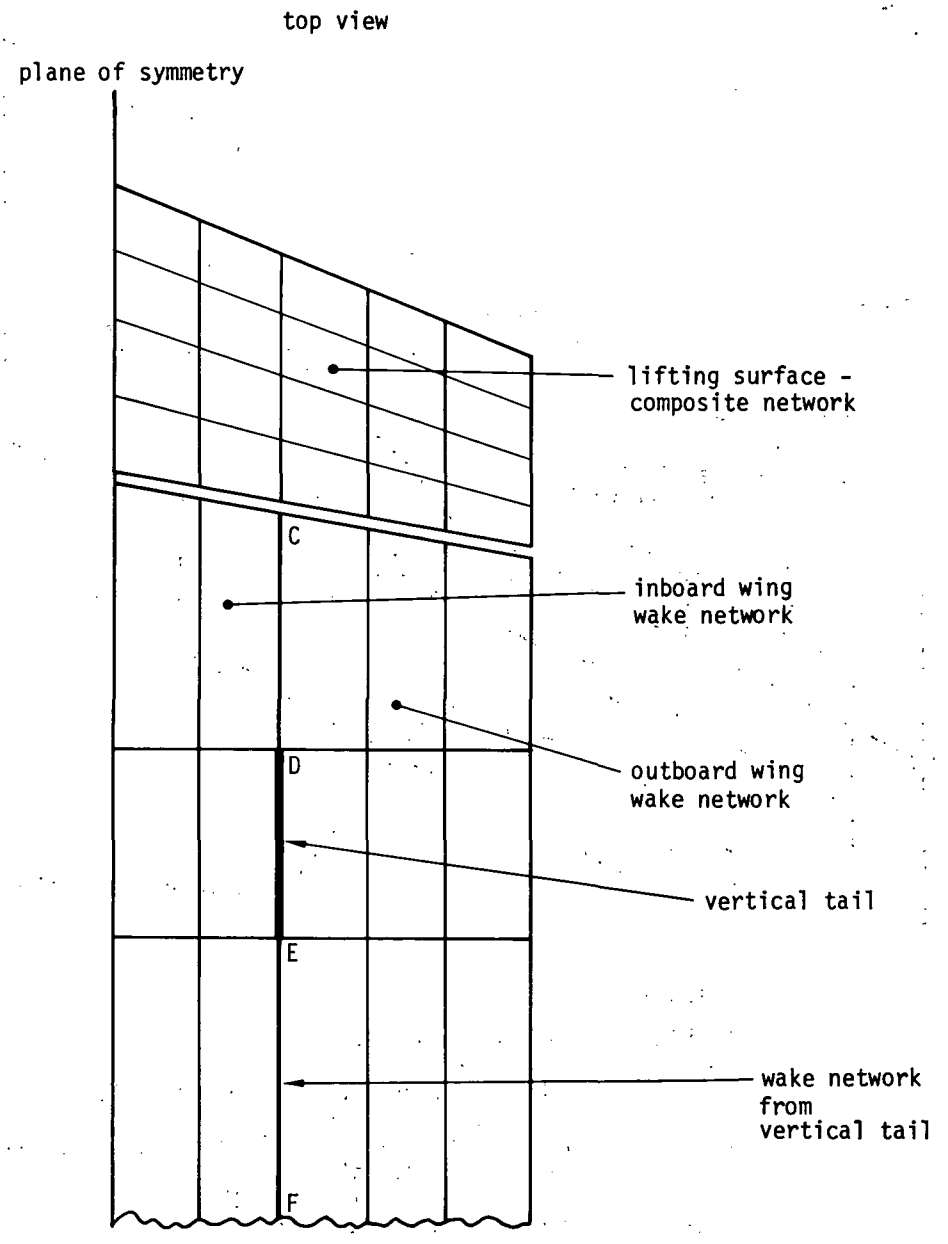



networks

| | |
|---|---|
| CDEFBA | outboard wing wake |
| CDEFHG | inboard wing wake |
| DEJI | inboard and outboard halves of vertical tail above the wing wake |
| DEML | inboard and outboard halves of vertical tail below the wing wake |
| EFKJ | vertical tail wake above the wing wake |
| EFNM | vertical tail wake below the wing wake |

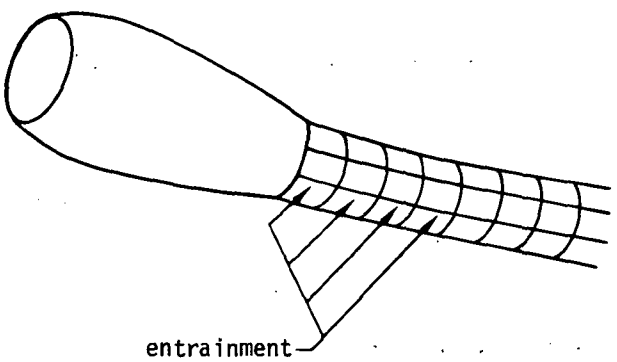
(a) network boundaries

Figure B.42 - Example of network boundaries for vertical tail in the wake of a wing

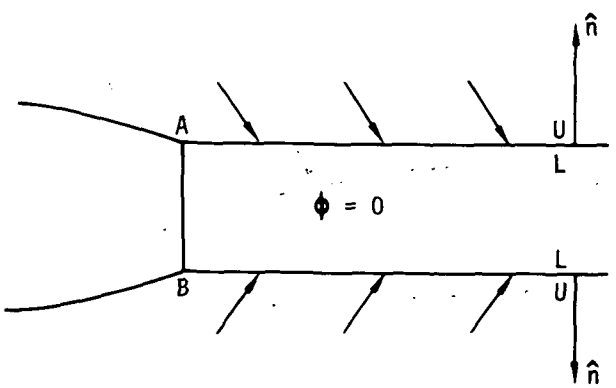



(b) paneling constraints, wake network

Figure B.42 - Concluded

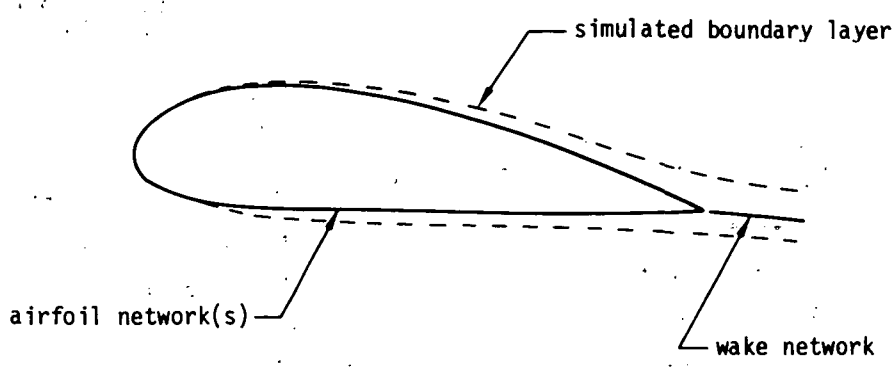



(a) physical model

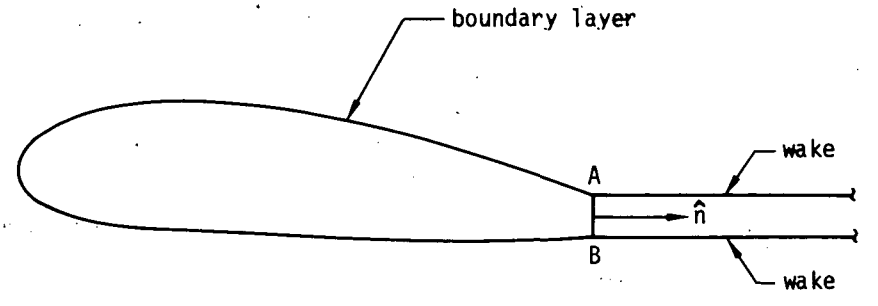



(b) network model

Figure B.43 - Example of entrainment by an exit stream tube




(a) linearized surface modeling




(b) exact surface modeling

Figure B.44 - Simulation of boundary layer on an airfoil and wake

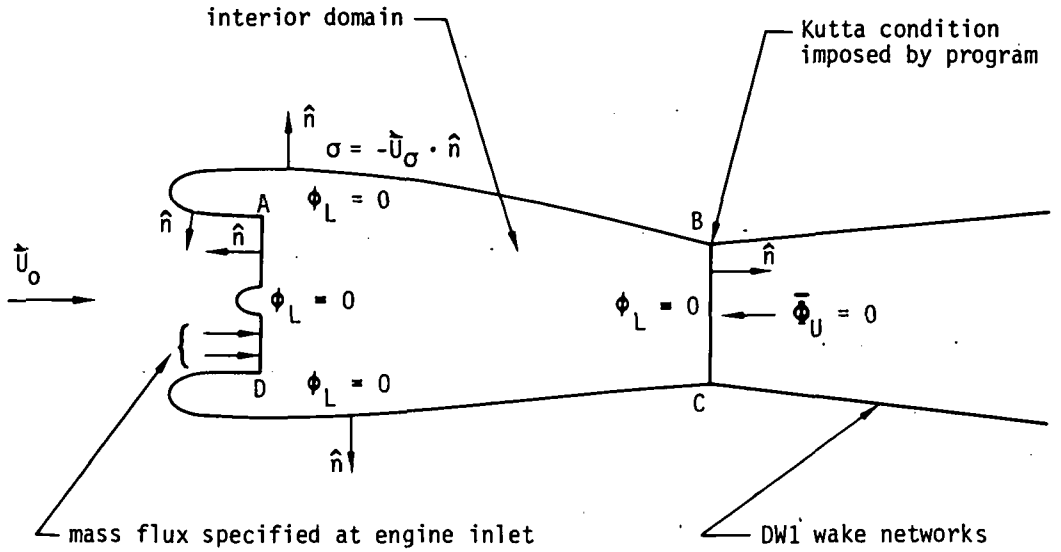



Figure B.45 - Modeling of nacelle in subsonic flow

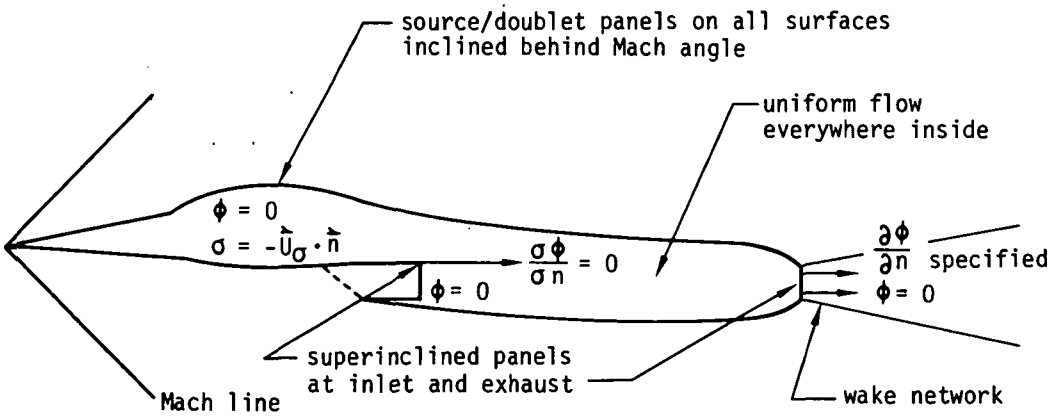
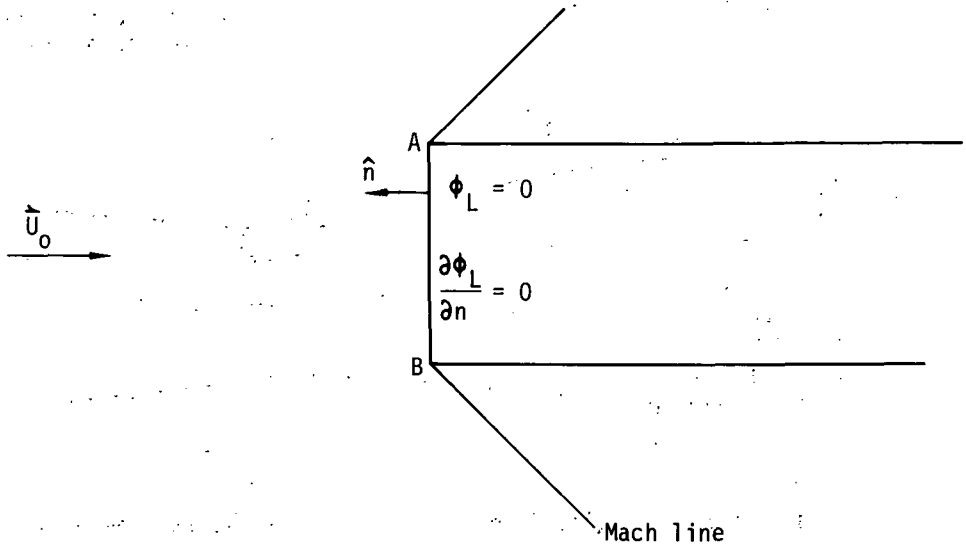
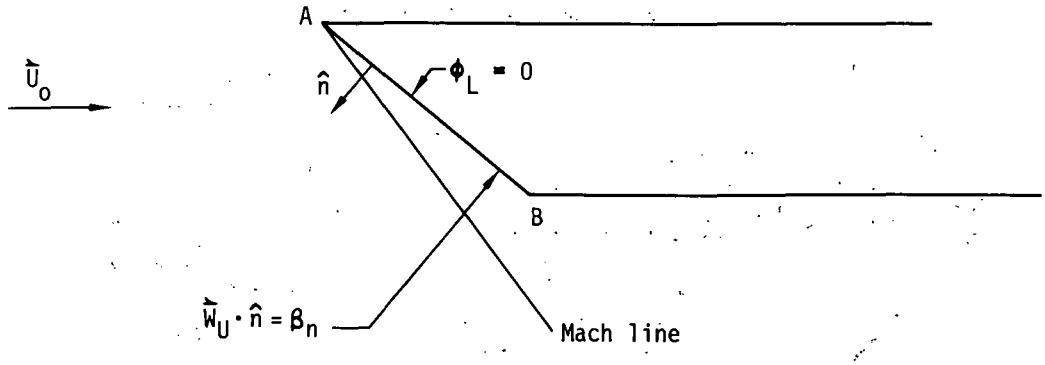



Figure B.46 - Example of combined use of composite panels and superinclined panels




(a) superinclined network




(b) subinclined network

Figure B.47 - Models of engine inlet in supersonic flow

| | |
|---|---|
| isentropic | $\frac{2}{\gamma M_\infty^2}\left\{\left[1+\frac{\gamma-1}{2}\left(1-\frac{V^2-2\Delta E}{U_\infty^2}\right)M_\infty^2\right]^{\frac{\gamma}{\gamma-1}}-1\right\}$ |
| linear | $-2\frac{u}{U_\infty}$ |
| second order | $1-\frac{V^2-2\Delta E}{U_\infty^2}+M_\infty^2\frac{(u+\Delta U)^2}{U_\infty^2}$ |
| reduced second order | $1-\frac{V^2-2\Delta E}{U_\infty^2}$ |
| slender body | $-2\left[\frac{u}{U_\infty}+\frac{\frac{1}{2}\left(v^2+w^2\right)+v\Delta V+w\Delta W}{U_\infty^2}\right]$ |

(a) $C_p$ local pressure coefficient

Figure B.48 - Relations for the local pressure coefficient, local Mach number and critical (sonic) pressure coefficient

| | |
|---|---|
| isentropic | $\dfrac{\frac{V}{U_\infty} M_\infty}{\left[1 + \frac{\gamma - 1}{2}\left(1 - \frac{V^2 - 2\Delta E}{U_\infty^2}\right) M_\infty^2\right]^{\frac{1}{2}}}$ |
| linear | $\left\{\dfrac{1 - \frac{1}{2} C_p}{1 + \frac{1}{2}(\gamma - 1) M_\infty^2 C_p}\right\}^{\frac{1}{2}} M_\infty$ |
| second order | $\dfrac{\frac{V}{U_\infty} M_\infty}{\left[1 + \frac{\gamma - 1}{2}\left(1 - \frac{V^2 - 2\Delta E}{U_\infty^2}\right) M_\infty^2\right]^{\frac{1}{2}}}$ |
| reduced second order | $\left\{\dfrac{1 - C_p + \frac{2\Delta E}{U_\infty^2}}{1 + \frac{1}{2}(\gamma - 1) M_\infty^2 C_p}\right\}^{\frac{1}{2}} M_\infty$ |
| slender body | $\left\{\dfrac{1 - C_p}{1 + \frac{1}{2}(\gamma - 1) M_\infty^2 C_p}\right\}^{\frac{1}{2}} M_\infty$ |

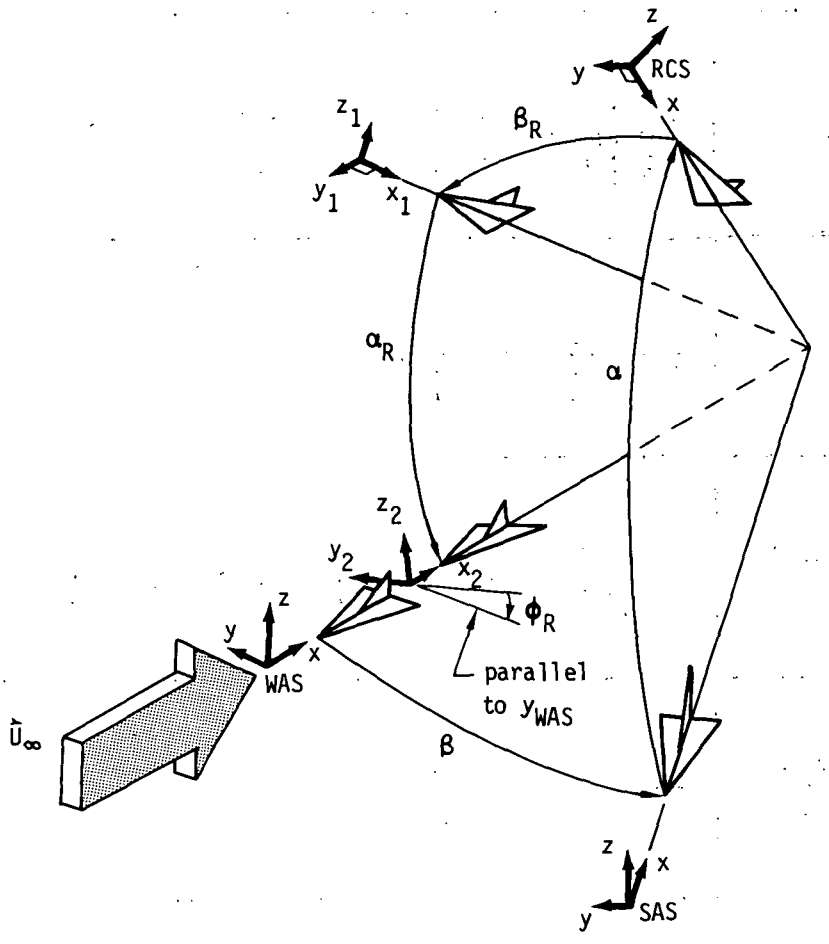
(b) local Mach number

Figure B.48 - Continued

| | |
|---|---|
| isentropic | $\frac{2}{\gamma M_\infty^2}\left\{\left[\frac{2}{\gamma+1}+\frac{\gamma-1}{\gamma+1}M_\infty^2\left(1+\frac{2\Delta E}{U_\infty^2}\right)\right]^{\frac{\gamma}{\gamma-1}}-1\right\}$ |
| linear | $-\frac{2}{\gamma+1}\left\{\frac{1}{M_\infty^2}-\left(1+\frac{2\Delta E}{U_\infty^2}\right)\right\}$ |
| second order | $\frac{1}{(\gamma+1)^2}\left\{2\left(\gamma+M_\infty^2\right)\left(1+\frac{2\Delta E}{U_\infty^2}\right)-M_\infty^2-(2\gamma+1)\frac{1}{M_\infty^2}\right\}$ |
| reduced second order | $-\frac{2}{\gamma+1}\left\{\frac{1}{M_\infty^2}-\left(1+\frac{2\Delta E}{U_\infty^2}\right)\right\}$ |
| slender body | $-\frac{2}{\gamma+1}\left\{\frac{1}{M_\infty^2}-\left(1+\frac{2\Delta E}{U_\infty^2}\right)\right\}$ |

(c) critical pressure coefficient

Figure B.48 - Concluded




notes:

1. for clarity, axes are shown ahead of rotation point
2. arrows show positive values for $\beta$, $\alpha$, $\beta_R$, $\alpha_R$ and $\phi_R$
3. sequence 1: from WAS to RCS
   a. $\psi = \beta$ about $z_{WAS}$ ⇨ SAS
   b. $\theta = \alpha$ about $y_{SAS}$ ⇨ RCS
4. sequence 2: from RCS to WAS
   a. $\psi = -\beta_R$ about $z_{RCS}$ ⇨ $x_1 y_1 z_1$
   b. $\theta = -\alpha_R$ about $y_1$ ⇨ $x_2 y_2 z_2$
   c. $\phi = \phi_R$ about $x_2$ ⇨ WAS

Figure B.49 - Two Euler angle sequences; from WAS to RCS and back to WAS

notes:

1. positive directions of force coefficients, moment coefficients, and angles are indicated by arrows
2. for clarity, origins of wind and stability axes have been displaced from the center of gravity
3. wind tunnel

| axis system: | notation |
|---|---|
| body | $x, y, z$ |
| stability | $x_s, y_s, z_s$ |
| wind | $x_w, y_w, z_w$ |




Figure B.50 - Wind tunnel axis systems, showing direction and sense of force and moment coefficients, angle of attack and sideslip

## C.0 Execution of PAN AIR for Large Problems

As the size of a PAN AIR problem increases, certain simplified approaches to execution built into the MEC module may no longer be desirable. This appendix discusses some of the specialized approaches and control card modifications which expedite the solution of larger problems using PAN AIR. The user is urged to gain familiarity with the PAN AIR system by first running fairly small problems (e.g., less than 100 panels) before attempting to run a large problem through the system.

## C.1 When to Use the Special Approaches

Several variables enter into the determination of whether the special approaches discussed below should be used to execute PAN AIR. They are: the amount of printed output, the amount of CPU time, and the amount of disk file space. These variables are roughly parameterized by the number of panels in the problem. However, additional compensating factors not given above make it almost impossible to say precisely that a particular problem is sufficiently large to require this special treatment. However, as a general guide, it is recommended that the user start with small problems and slowly increase the problem size until one of the following errors or situations occurs:

1) FTN Fatal Error 83 (Output line limit exceeded),

2) Extremely slow turnaround results due to long CPU time estimates on the job card, and

3) SDMS error indicating that insufficient file space was available.

If one of the above situations holds or if for a given problem, the product of the number of panels and the number of solutions exceeds 250, then the following special approaches to the execution of PAN AIR are recommended.

## C.2 Output Line Limits

If the printed output of any one module exceeds a certain number of lines (e.g., on the NASA Ames system the number is 5000), a fatal FORTRAN Error 83 occurs. Typically, this will occur in either the CDP, PDP and/or DQG modules depending on the problem size and output options which have been selected. To avoid this error it is necessary to modify the control card that causes the module to execute. For example, if execution of DQG fails due to a FORTRAN Error 83, then the job should be re-submitted with the card calling DQG module into execution, namely,

DQG.

replaced by a card of the form:

DQG(PL=nnnnnn).

where nnnnnn is the expected number of lines of printed output.

If the control cards were generated by MEC, it will be necessary to create a deck of control cards from the file MECCC, modify the control cards as necessary, and submit the modified control cards as a new job (see Section 8.5). This is because MEC does not add the PL= specification to the output on MECCC.

Often it is desirable to delay printing all or some of the output data from a PAN AIR run. This is accomplished by specifying a file on which the printed output is to be written. If the file is saved by the user, then later a job can be submitted which will copy the file to the line printer. To store the output from a PAN AIR module on a file, it will be necessary to add to the PAN AIR execution deck the appropriate control cards to define this file. It will also be necessary to assure that the file is saved before the end of the job by adding appropriate control cards (see your installation's OS User's Guide). Finally, the execution control card for each module affected should be modified as follows:

| | | |
|---|---|---|
| DQG. | becomes | DQG(INPUT,YOURFIL). |
| DQG(PL=100000) | becomes | DQG(PL=100000,INPUT,YOURFIL). |

## C.3 Memory Requirements

Table 1.5 of PAN AIR Maintenance Document lists the minimum central memory (CM) requirements for each module in PAN AIR. For large problems, execution efficiency can be increased and cost decreased (within limits) by increasing the amount of central memory available to the MAG module. However, any increase in the amount of central memory beyond 210K, 300K or 400K (depending on the type of flow symmetry in the problem) will not increase the efficiency of MAG. Since there is an additional cost incurred for requesting large amounts of memory, one solution is to break up the PAN AIR run into several jobs. The first job will run the MEC, DIP and DQG modules, the second job will run the MEC and MAG modules and the third job will run the RMS, RHS, MDG, PDP, CDP and the PPP modules. Thus, the requested memory could be much smaller for the modules which do not benefit from the extra storage. The other solution would be to use the REDUCE or RFL control cards (see your installation's OS User's Guide) to adjust CM on a module by module basis.

## C.4 Special Procedures

Some modules of PAN AIR require considerably more resources than others. Thus, a particularly large PAN AIR run should be submitted on a deferred priority basis to run over a weekend, for example. However, a

trivial user error in the input data, discovered by DIP, might not be communicated for 24 to 48 hours. Therefore, when dealing with large problems, it is useful to reduce turnaround time by breaking up the run into several jobs.

Three approaches are suggested to do this. In the case of moderately large jobs , it is recommended that DIP amd DQG be run in one job; then MAG should be run as a job by itself; and, finally, RMS, RHS, MDG, PDP, and CDP should be run. For larger jobs and, especially, jobs with many solutions it may be advisable to separate execution of RMS, RHS and MDG from the execution of the post-processing modules PDP, CDP and PPP. For the very large jobs with many solutions, it may be advisable to run each module as a separate job. The MEC module must be run as a first step in all of the jobs. Care must be taken to assure that the appropriate database files have been saved for use in other jobs (see Section 6).

When a PAN AIR execution is broken up into several jobs, it is useful to add appropriate purge statements at the beginning of the job to purge all database files created by the job. In this manner, if the job fails during execution because of a system hardware error and a re-run attempt is made, there will be no possibility that an older copy of a database file will be used during the re-run. On some systems (notably Boeing), if the files are not purged, the job cannot be re-run. Specification of re-run conditions are sometimes required on the job card . Check with the representatives of your computer installation to learn how the re-run conditions are specified.

## C.5 Database Storage Requirements

Large problems require large amounts of disk space for database storage. (A 500 panel problem will require six-million words for permanent data bases and several million words for temporary data bases.) Depending upon the policies of the operating system, it may be necessary to pre-arrange such a run. If several people are sharing permanent file space on the same disk device and are using large amounts of space simultaneously, the disk may appear filled even though, in principle, there might have been enough room on the disk at the beginning of the job. For this reason, it is strongly advised that those who run large problems obtain a private disk. Installations which offer removable disk packs may be subject to the same problem.

## C.7 Cost Estimates

Cost estimates are not easy to give. Different installations have different billing algorithms. Figure C-1 is offered as a guide only. It specifies cost of PAN AIR (Version 1.0) execution (DQG through MDG modules) on the NASA/Ames 7600 computer system. The total cost of the MEC and DIP modules is very nominal. The cost of PDP, CDP and PPP modules depend on the number of user options, and therefore are not given in Table C-1. The data in this table is for a PAN AIR run in NASA-Ames CDC 7600 computer installation at normal priority. It should be noted that the cost will be approximately half of that listed in Table C-1 if PAN AIR is run at deferred priority.

| Case Name | Number of Panels | PAN AIR Module | CPU (sec) | Disk I/O ($10^6$ words) | Cost (dollars) |
|---|---|---|---|---|---|
| NASA Wing-Body | 250 | DQG | 45.6 | 18.8 | 35.52 |
| | (3 networks) | MAG | 184.9 | 17.7 | 98.74 |
| | | RMS | 8.6 | 2.4 | 4.93 |
| | | RHS | 2.9 | 10.5 | 16.96 |
| | | MDG | 19.3 | 23.6 | 38.28 |
| Small Weapons Carriage Airplane | 213 (15 networks) | DQG | 32.9 | 23.3 | 40.75 |
| | | MAG | 85.5 | 9.7 | 30.30 |
| | | RMS | 5.5 | 17.7 | 3.77 |
| | | RHS | 6.9 | 8.0 | 13.05 |
| | | MDG | 14.9 | 15.7 | 26.25 |

Table C-1 Example of PAN AIR (Version 1.0 of May, 1980) cost for large problems. (NASA Ames 7600 at normal priority)

## D.0 Summary of DIP Input Records

The DIP input records are listed below by data groups. For each record only the primary keyword, secondary keywords, basic options and formats are listed. Detailed descriptions of each record are given in section 7.

### D.1 Global Data Group

Record G1. Global Data Group Identifier

```
<BEGIN GLOBAL DATA = <Solution-update-option>>
                      NEW
                      REPLACE
                      UPDATE
```

Record G2. Problem Identification

```
<PID = problem identification>
```

Record G3. User Identification

```
<UID = user identification>
```

Record G4. Configuration and Flow Symmetry

```
<CONFIGURATION = List(n)>

List(1) = ASYMMETRIC-GEOMETRY

List(2) = FIRST-PLANE <direction-numbers <point>><Flow-type>
                                                  ASYMMETRIC-FLOW
                                                  SYMMETRIC-FLOW
                                                  GROUND-EFFECT

List(3) = <List(2)> SECOND-PLANE<direction-numbers> <Flow-type>
                                                      ASYMMETRIC-FLOW
                                                      SYMMETRIC-FLOW
                                                      GROUND-EFFECT
```

Record G5. Compressibility Data

```
<MACH = mach> <CALPHA = calpha>        <CBETA = cbeta>
```

Record Set G6. Global Onset Flow Record Set

Format Option 1: Header Record and Parameter Values Records

```
Header Record     <ALPHA><BETA><UINF><WM><WDC><WCP><SID>
Parameter Values:  alpha   beta   uinf   wm   wdc   wcp   sid
```

Format Option 2: Separate Record for Each Parameter

```
<ALPHA = alpha(1), alpha (2),..., alpha(N)>
<BETA = beta(1), beta(2),..., beta(N)>
<UINF = uinf(1), uinf(2),..., uinf(N)>
<WM = wm(1), wm(2),..., wm(N)>
<WDC = wdcx(1), wdcy(1), wdcz(1), wdcx(2),..., wdcz(N)>
<WCP = wcpx(1), wcpy(1), wcpz(1), wcpx(2),..., wcpz(N)>
<SID = solution-id(1),..., solution-id(N)>
```

Record G7. Tolerance for Geometric Edge Matching

```
<TOLERANCE FOR GEOMETRIC EDGE MATCHING = {tolerance}>
```

Record G8. Surface Selection Options

```
<SURFACE SELECTION =  {{Surface(s)}}>
                       UPPER
                       LOWER
                       UPLO          (upper minus lower)
                       LOUP          (lower minus upper)
                       AVERAGE
```

Record G9. Selection of Velocity Computation Method

```
<SELECTION OF VELOCITY COMPUTATION =   {{Method(s)}}>
                                        BOUNDARY-CONDITION
                                        VIC-LAMBDA
```

Record G10. Computation Option for Pressures

```
<COMPUTATION OPTION FOR PRESSURES =     {Option}>
                                        UNIFORM-ONSET-FLOW
                                        TOTAL-ONSET-FLOW
                                        COMPRESSIBILITY-VECTOR
```

Record G11. Velocity Correction Options

```
<VELOCITY CORRECTIONS = {{Correction(s)}}>
                         NONE
                         SA1
                         SA2
```

Record G12. Pressure Coefficient Rules

```
<PRESSURE COEFFICIENT RULES =   {{Rule(s)}}>
                                 ISENTROPIC
                                 LINEAR
                                 SECOND-ORDER
                                 REDUCED-SECOND-ORDER
                                 SLENDER-BODY
```

Record G13. Ratio of Specific Heats

<RATIO OF SPECIFIC HEATS = {{gamma(s)}}>

Record G14. Reference Velocity for Pressure

<REFERENCE VELOCITY FOR PRESSURE = {{rvp(s)}}>

Record G15. Store Velocity Influence Coefficient Matrix

<STORE VIC MATRIX>

Record G16. Store Local Onset Flow

<STORE LOCAL ONSET FLOW>

Record G17. Checkout Print Options

<CHECKOUT PRINTS = {Module(1), List(1), Module(2), List(2)}>

D.2 Network Data Group

Record N1. Network Data Group Identifier

<BEGIN NETWORK DATA>

Record Set N2. Network Identifier Record Set

Record N2a. Network Identifier

NETWORK = List(n)

List(1) = <network-id> {number-rows, number-columns} <NEW>

List(2) = {network-id, number-rows, number-columns} REPLACE

List(3) = {network-id} SOLUTION-UPDATE

List(4) = {network-id} DELETE

Record N2b. Grid Point Coordinates

{x(1), y(1), z(1), x(2), y(2), z(2),...}

Record N3 (and record G15). Store Velocity Influence Coefficient Matrix

<STORE VIC MATRIX>

Record N4 (and record G16). Store Local Onset Flow

<STORE LOCAL ONSET FLOW>

Record N5. Reflection in Plane of Symmetry Tag

```
<SYMMETRY PLANE NETWORK = {Plane}>
                          FIRST-PLANE
                          SECOND-PLANE
```

Record N6. Wake Flow Properties Tag

```
<WAKE FLOW PROPERTIES TAG>
```

Record N7. Triangular Panel Tolerance

```
<TRIANGULAR PANEL TOLERANCE = {tolerance}>
```

Record N8. Network and Edge Update Tag

```
<UPDATE TAG = <edge-number-list>>
```

Record N9. Boundary Condition Specification

```
<BOUNDARY CONDITION = <Level> {Class}   {{Subclass(es)}}>
                      LOCAL
                      OVERALL
```

Record N10. Method of Velocity Computation

```
<METHOD OF VELOCITY COMPUTATION = {Method}>
                                  LOWER-SURFACE-STAGNATION
                                  UPPER-SURFACE-STAGNATION
                                  NONSTAGNATION
```

Record N11. Singularity Types

```
<SINGULARITY TYPES = {Source}   {Doublet}>
                     NOS        NOD
                     SA         DA
                     SD1        DD1
                                DW1
                                DW2
```

Record N12. Edge Control Point Locations

```
<EDGE CONTROL POINT LOCATIONS =   <Type(s) = edge-number(s)>>
                                  SNE, source-network-edge(s)
                                  DNE, doublet-network-edge(s)
```

Record N13. Remove Doublet Edge Matching

```
<NO DOUBLET EDGE MATCHING =   {{edge-number(s)}}>
```

Record Set N14. Closure Edge Boundary Condition Record Set

Record N14a. Closure Edge Condition Identifier and Locator

```
<CLOSURE EDGE CONDITION =     {Type = edge-number}>
                               SNE, source-network-edge
                               DNE, doublet-network-edge
```

Record N14b. Closure Term

TERM = {Term}

Record N14c. Closure Solutions List

<SOLUTIONS = {{solution-id(I)}}>

Record N14d. Closure Numerical Values

{{value(s)}}

Record Set N15. Coefficients of General Boundary Condition Equation Record Set

Record N15a. Coefficients of General Boundary Condition Equation Identifier

<COEFFICIENTS OF GENERAL BOUNDARY CONDITION EQUATION>

Record N15b. Equation Term

TERM = {Term}

Record N15c. Equation Solutions List

<SOLUTIONS = {{solution-id(I)}}>

Record N15d. Equation Control Point Locations

POINTS = {Location}
ALL-CONTROL-POINTS
CENTER-CONTROL-POINTS
EDGE-CONTROL-POINTS
ADDITIONAL-CONTROL-POINTS

Record N15e. Equation Numerical Values

{{value(s)}}

Record Set N16. Tangent Vectors for Design Record Set

Record N16a. Tangent Vectors for Design Identifier

<TANGENT VECTORS FOR DESIGN>

Record N16b. Tangent Vectors Term

TERM = {{Term(s)}}

Record N16c. Tangent Vectors Scaling

<UNALTERED>

Record N16d. Tangent Vectors Solutions List

<SOLUTIONS = {{solution-id(I)}}>

Record N16e. Tangent Vectors Control Point Locations

POINTS = {Location}
ALL-CONTROL-POINTS
CENTER-CONTROL-POINTS
EDGE-CONTROL-POINTS
ADDITIONAL-CONTROL-POINTS

Record N16f. Tangent Vectors Numerical Values

<{{values}}>

Record N16g. Tangent Vectors Standard Numerical Values

<Method>
COMPRESSIBILITY-DIRECTION
MID-POINT = {originating-edge-number}
1 (from edge 1 to edge 3)
2 (from edge 2 to edge 4)
3 (from edge 3 to edge 1)
4 (from edge 4 to edge 2)

Record Set N17. Specified Flow Record Set

Record N17a. Specified Flow Identifier

<SPECIFIED FLOW>

Record N17b. Specified Flow Term

TERM = {equation-number}
equation-number = 1 or 2

Record N17c. Specified Flow Symmetries

<INPUT-IMAGES = {{Image(s)}}>
INPUT
1ST
2ND
3RD

Record N17d. Specified Flow Solutions List

<SOLUTIONS = {{solution-id(I)}}>

Record N17e. Specified Flow Control Point Locations

POINTS = {Location}
ALL-CONTROL POINTS
CENTER-CONTROL POINTS
EDGE-CONTROL POINTS
ADDITIONAL-CONTROL POINTS

Record N17f. Specified Flow Numerical Values

{{value(s)}}

Record Set N18. Local Onset Flow Record Set

Record N18a. Local Onset Flow Identifier

<LOCAL ONSET FLOW>

Record N18b. Local Onset Flow Term

TERM = {Term}
ALPHA-BETA-MAGNITUDE
VXYZ

Record N18c. Local Onset Flow Symmetries

<INPUT-IMAGES = {{Image(s)}}>
INPUT
1ST
2ND
3RD

Records N18d. Local Onset Flow Solutions List

<SOLUTIONS = {{solution-id(I)}}>

Record N18e. Local Onset Flow Control Point Locations

POINTS = {Location}
ALL-CONTROL-POINTS
CENTER-CONTROL-POINTS
EDGE-CONTROL-POINTS
ADDITIONAL-CONTROL-POINTS

Record N18f. Local Onset Flow Numerical Values

{{values}}

D.3 Geometric Edge Matching Data Group

Record GE1. Geometric Edge Matching Data Group Identifier

<BEGIN GEOMETRIC EDGE MATCHING DATA>

Record GE2. Abutment Definition

< ABUTMENT {{= network-id(I), edge number(I) <end-point-pair(I) / ENTIRE-EDGE>}}>

Record GE3. Abutment in Planes of Symmetry

<PLANE OF SYMMETRY = {Plane}>
FIRST-PLANE-OF-SYMMETRY
SECOND-PLANE-OF-SYMMETRY
BOTH-PLANES-OF-SYMMETRY

Record GE4. Smooth Edge Treatment Option

<SMOOTH EDGE TREATMENT>

D.4 Flow Properties Data Group

Record FP1. Flow Properties Data Group Identifier

<BEGIN FLOW PROPERTIES DATA = <Update-option>>
NEW
REPLACE
UPDATE

Record SF1. Surface Flow Properties Data Subgroup Identifier

<SURFACE FLOW PROPERTIES = <case-id>>

Record SF2. Networks and Images Selection

<NETWORKS-IMAGES {{= network-id(I) <Images(I)> <Orientation(I)>}}>
INPUT RETAIN
1ST REVERSE
2ND
3RD

Record SF3. Solutions List

<SOLUTIONS = {{solution-id(I)}}>

Record Set SF4. Calculation Point Locations Record Set

Record SF4a. Point Types

<POINTS = {{Location(s)}}>
GRID-POINTS
ALL-CONTROL-POINTS
CENTER-CONTROL-POINTS
EDGE-CONTROL-POINTS
ADDITIONAL-CONTROL-POINTS
ARBITRARY-POINTS

Record SF4b. Arbitrary Points

<{{panel-row, panel-column, network-id, {{x(I), y(I), z(I)}} }}>

Record SF5 (and record G8). Surface Selection Options

<SURFACE SELECTION = {{Surface(s)}}>
UPPER
LOWER
UPLO (upper minus lower)
LOUP (lower minus upper)
AVERAGE

Record SF6 (and record G9). Selection of Velocity Computation Method

```
<SELECTION OF VELOCITY COMPUTATION =  {{Method(s)}}>
                                       BOUNDARY-CONDITION
                                       VIC-LAMBDA
```

Record SF7 (and record G10). Computation Option for Pressures

```
<COMPUTATION OPTION FOR PRESSURES =  {Option}>
                                     UNIFORM-ONSET-FLOW
                                     TOTAL-ONSET-FLOW
                                     COMPRESSIBILITY-VECTOR
```

Record SF8 (and record G13). Ratio of Specific Heats

```
<RATIO OF SPECIFIC HEATS =  {{gamma(s)}}>
```

Record SF9 (and record G14). Reference Velocity for Pressure

```
<REFERENCE VELOCITY FOR PRESSURE =  {{rvp(s)}}>
```

Record Set SF10. Printout Options Record Set

Record SF10a. Printout Options

```
<PRINTOUT =  <Option(s)>>
              Integers or Keywords, listed in table 7.9
              ALL (all allowable options)
```

Record SF10b (and record G11). Velocity Correction Options

```
<VELOCITY CORRECTIONS =  {{Correction(s)}}>
                         NONE
                         SA1
                         SA2
```

Record SF10c (and record G12). Pressure Coefficient Rules

```
<PRESSURE COEFFICIENT RULES =  {{Rule(s)}}>
                               ISENTROPIC
                               LINEAR
                               SECOND-ORDER
                               REDUCED-SECOND-ORDER
                               SLENDER-BODY
```

Record Set SF11. Data Base Options Record Set

Record SF11a. Data Base Options

```
<DATA BASE =  <Option(s)>>
               Integers or Keywords, listed in table 7.9.
               ALL (all allowable options)
```

Record SF11b (and record G11). Velocity Correction Options

```
<VELOCITY CORRECTIONS =    {{Correction(s)}}>
                             NONE
                             SA1
                             SA2
```

Record SF11c (and record G12). Pressure Coefficient Rules

```
<PRESSURE COEFFICIENT RULES =   {{Rule(s)}}>
                                  ISENTROPIC
                                  LINEAR
                                  SECOND-ORDER
                                  REDUCED-SECOND-ORDER
                                  SLENDER-BODY
```

Record FM1. Forces and Moments Subgroup Identifier

```
<FORCES AND MOMENTS>
```

Record FM2. Reference Parameters

```
<REFERENCE PARAMETERS =    {{Parameter, value}}>
                             SR
                             CR
                             BR
```

Record FM3. Axis Systems

```
<AXIS SYSTEMS =   {{List, <values>}}>
                    RCS   <mrp>
      Parameter Defaults:   0.,0.,0.
                    SAS   <mrp>
      Parameter Defaults:   RCS values
                    WAS   <mrp>
      Parameter Defaults:   RCS values
                    BAS   <Euler angles <mrp>>
      Parameter Defaults:   180.,0.,180., 0.,0.,0.
```

Record FM4. Solutions List

```
<SOLUTIONS =   {{solution-id(I)}}>
```

Record FM5. Printout Options

<PRINTOUT = {{Parameter(s)}}>

General Parameter Options:
NO: no data printed
SAME: same options as specified for DATA BASE (record FM6)
ALL: all available specific options listed below

Specific Parameter Options:

| | | |
|---|---|---|
| PANELS | Selected-axis-system(s) | |
| | RCS: Default Parameter<br>SAS<br>WAS<br>BAS | see record FM3 |
| COLSUM | Selected-axis-system(s) | |
| | RCS: Default Parameter<br>SAS<br>WAS<br>BAS | see record FM3 |
| NETWORK CONFIGURATION | | |

Record FM6. Data Base Options

<DATA BASE = {{Parameter(s)}}>

Record FM7. Case Identifier

CASE = <case-id>

Record FM8. Networks and Images Selection

<NETWORKS-IMAGES {{= network-id(I) <Images(I)><Orientation(I)><FM-Option (I)>}}>

| | | |
|---|---|---|
| INPUT | RETAIN | PRESSURE-ONLY |
| IST | REVERSE | MOMENTUM-TRANSFER |
| 2ND | | |
| 3RD | | |

Record FM9. Edge Force Calculation

<EDGE FORCE CALCULATION {{= network-id(I), edge-number(s)}}>

Record FM10. Moment Axis

<MOMENT AXIS = {x(1),y(1),z(1),x(2),y(2),z(2)}>

Record FM11. Local Reference Parameters

<LOCAL REFERENCE PARAMETERS = {{Parameter, value}}>

SR
CR

Record FM12 (and record G8). Surface Selection Option

```
<SURFACE SELECTION =    {Surface}>
                        UPPER
                        LOWER
                        UPLO (upper plus lower)
                        LOUP (lower plus upper)
                        AVERAGE (program replaces by LOUP)
```

Record FM13 (and record G9). Selection of Velocity Computation Method

```
<SELECTION OF VELOCITY COMPUTATION =  {{Method(s)}}>
                                      BOUNDARY-CONDITION
                                      VIC-LAMBDA
```

Record FM14 (and record G10). Computation Option for Pressures

```
<COMPUTATION OPTION FOR PRESSURES =    {Option}>
                                       UNIFORM-ONSET-FLOW
                                       TOTAL-ONSET-FLOW
                                       COMPRESSIBILITY-VECTOR
```

Record FM15 (and record G11). Velocity Correction Options

```
<VELOCITY CORRECTIONS =  {{Correction(s)}}>
                         NONE
                         SA1
                         SA2
```

Record FM16 (and record G12). Pressure Coefficient Rules

```
<PRESSURE COEFFICIENT RULES = {{Rule(s)}}>
                              ISENTROPIC
                              LINEAR
                              SECOND-ORDER
                              REDUCED-SECOND-ORDER
                              SLENDER-BODY
```

Record FM17 (and record G13). Ratio of Specific Heats

```
<RATIO OF SPECIFIC HEATS =   {{gamma(s)}}>
```

Record FM18 (and record G14). Reference Velocity for Pressure

```
<REFERENCE VELOCITY FOR PRESSURE = {{rvp(s)}}>
```

Record FM19. Local Printout Options

```
<LOCAL PRINTOUT =  {{Parameter(s)}}>
```

Record FM20. Local Data Base Options

```
<LOCAL DATA BASE =   {{Parameter(s)}}>
```

Record FM21. Accumulation Options

```
<ACCUMULATE =    <Option(I)>>
```

D.5 Print-Plot Data Group

Record PP1. Print-Plot Data Group Identifier

<BEGIN PRINT PLOT DATA>

Record Set PP2. Geometry Data Record Set

Record PP2a. Geometry Data Identifier

<GEOMETRY DATA>

Record PP2b. Network Selection

<NETWORKS = {{network-id(I)}}>

Record Set PP3. Point Data Record Set

Record PP3a. Point Data Identifier

<POINT DATA>

Record PP3b. Case Selection

<CASES = {{case-id(I)}}>

Record PP3c. Solutions List

<SOLUTIONS = {{solution-id(I)}}>

Record PP3d. Networks and Images Selection

<NETWORKS-IMAGES {{= network-id(I) <Images(I)>}}>

Images(I): INPUT | 1ST | 2ND | 3RD

Record PP3e. Array Type

<ARRAY = < COLUMNS | ROWS > < CONTROL-POINTS | GRID-POINTS >>

Record Set PP4. Configuration Data Record Set

Record PP4a. Configuration Data Identifier

<CONFIGURATION DATA>

Record PP4b. Case Selection

<CASES = {{case-id(I)}}>

Record PP4c. Solutions List

<SOLUTIONS = {{solution-id(I)}}>

Record PP4d. Networks and Images Selection

<NETWORKS-IMAGES {{= network-id(I) <Images(I)> <PANELS> <COLSUM>}}>

INPUT
1ST
2ND
3RD

| 1. Report No. | 2. Government Accession No. | 3. Recipient's Catalog No. |
|---|---|---|
| NAS CR-3252 | | |

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16. Abstract

A comprehensive description of user problem definition for the PAN AIR (Panel Aerodynamics) system is given. PAN AIR solves the three dimensional linear integral equations of subsonic and supersonic flow. Influence coefficient methods are used which employ source and doublet panels as boundary surfaces. Both analysis and design boundary conditions can be used.

This User's Manual describes the information needed to use the PAN AIR system. The structure and organization of PAN AIR are described, including the job control and module execution control languages for execution of the program system. The engineering input data are described, including the mathematical and physical modeling requirements.

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|---|---|
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